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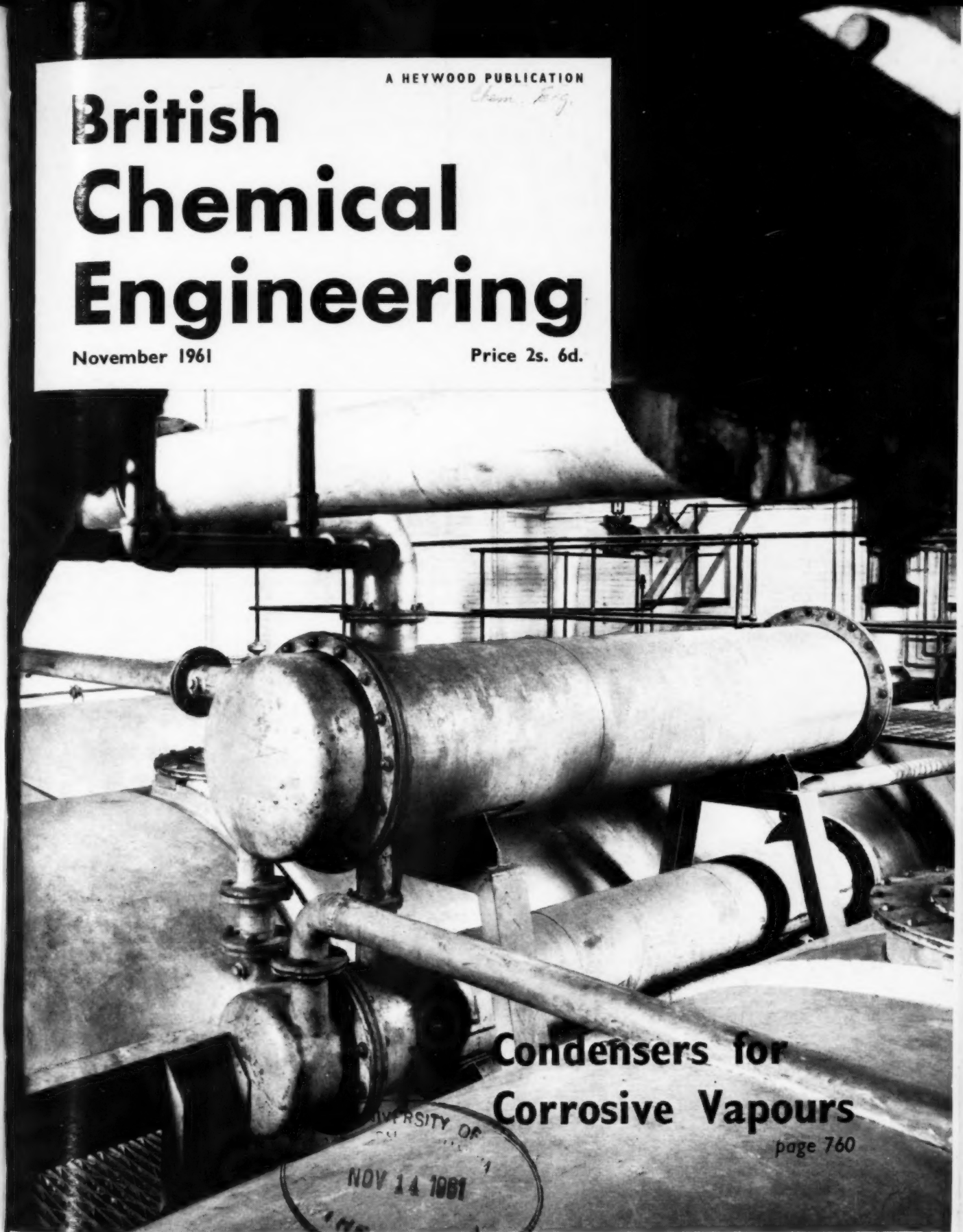

Condensers for Corrosive Vapours

page 760

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Fresh Water from the Ocean *(page 754)*
Improved Sieve Trays *(page 766*
Mechanism of Fluidization *(page 777)*
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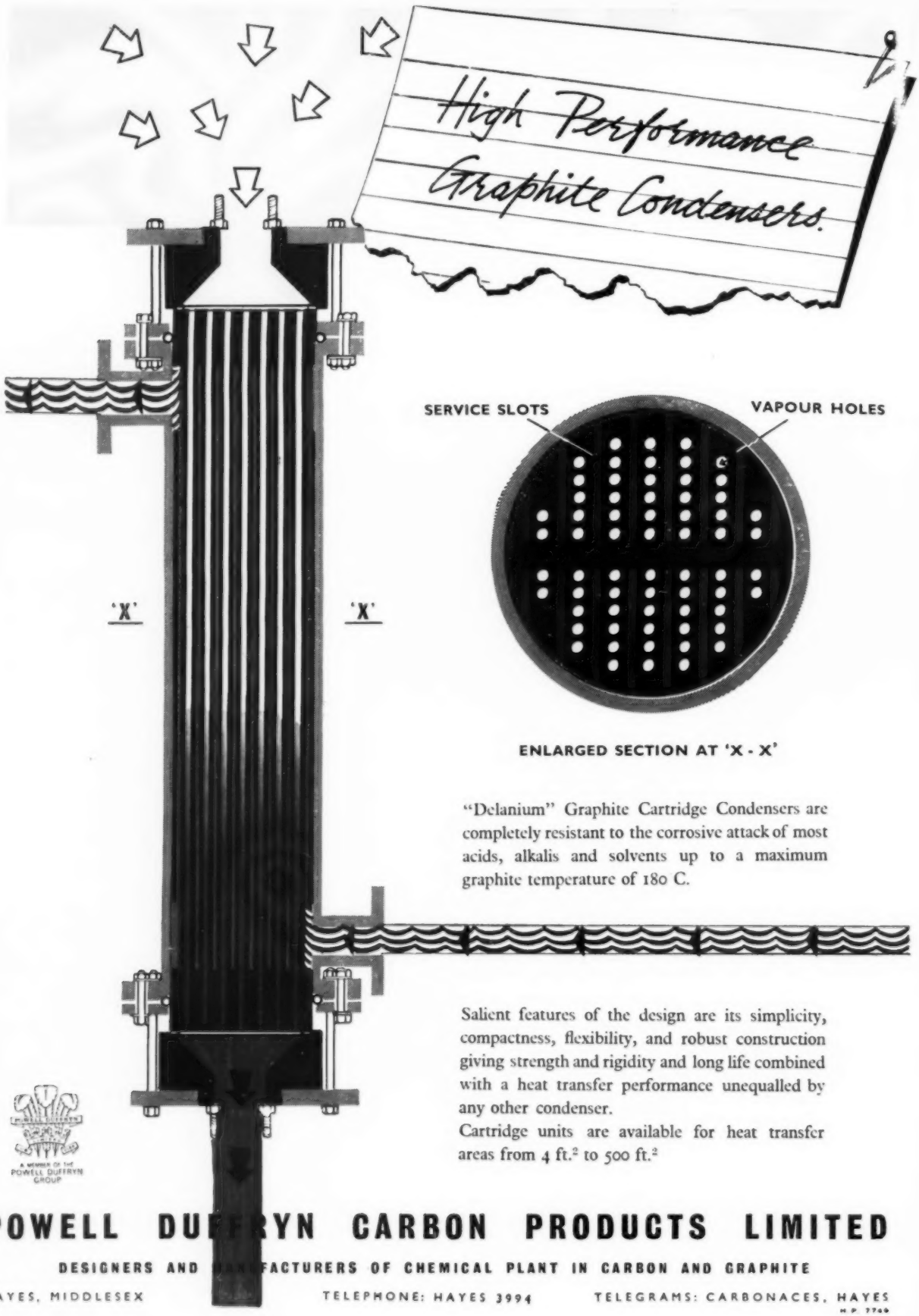

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DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Mass Transfer and Chemical Reaction

THE phenomenon of diffusion accompanied by chemical reaction occurs in many processes and certainly, in theory, the subject has been treated in the literature as much as its mathematical complexity permits. On the other hand, experimental work in the field is comparatively rare, hence the appearance of a recent Canadian paper based upon experimental work is all the more welcome.*

One part of this work was devoted to an experimental investigation of mass transfer coefficients without chemical reaction for solid/liquid systems in baffled agitated vessels. This work established that the Sherwood Number for mass transfer depends on the one-third power of the Schmidt Number and the 0.65 power of the stirrer Reynolds Number. The Schmidt Number exponent of one-third is in good agreement with the prediction of the boundary layer theory of mass transfer but the Reynolds group exponent is in disagreement with the laminar boundary layer theory but qualitatively it appears to be in agreement with the turbulent boundary layer concept.

So far as the reaction systems were concerned those selected were solid-liquid neutralisation such as, the systems benzoic acid-aqueous sodium hydroxide, and o-salicylic acid-aqueous sodium hydroxide. Reaction factors, that is the ratio between the mass transfer coefficient with chemical reaction to that without chemical reaction, were determined and were found to depend strongly on the concentration ratio of the reactants in a manner predicted quantitatively by the boundary layer theory, corrected for ionic effects upon the diffusivities of the reactants. The theory of ionic diffusion in a stagnant film was supported also by results obtained from experiments with diaphragm-type diffusion cells.

One thing for which the authors of this work can be commended in their article apart from the investigation proper is the potted historical background on theories of mass transfer, with and without chemical reaction. This embraced the diffusion layer theory, the penetration and surface renewal theories, the boundary layer theory and the theory of diffusion of ions in mixtures of electrolytes used by SHERWOOD and others to calculate the rate of mass transfer in the presence of ionic effects.

* J. MARANGOZIS and A. I. JOHNSON, *Canadian Journal of Chemical Engineering*, 1961, 39 (4) 152.

Detecting Leaks in Buried Pipes

A DEVICE is being developed at the laboratory of the Water Research Association at Medmenham, which is expected to facilitate the detection of small leaks in buried pipes. This device is now at an intermediate stage of its development in that signals which are transmitted by an instrument carrier in a buried pipe can be detected at the ground level above it.

A leak in a pipeline causes the pressure of the fluid to drop at that point, and measurements of pressure in a pipeline taken in this way would enable the position of leaks to be determined with great accuracy.

The medium selected for communicating between the transmitter inside the pipe and the detector on the ground is of some interest. Metal pipes have a screening effect on electromagnetic and electrostatic fields and it is difficult to transmit a signal of sufficient intensity by such means. Other methods are either incapable of being modulated to provide a telemetering signal or have other disadvantages. However, a magnetic field modulated at very low frequency is easily distinguishable from the earth's magnetic field and other interference, and this system has been adopted.

Two modifications of this method have been tested to the prototype stage. In the first, an electrical buzzer system interrupts current through a solenoid, but the magnetic field radiated is not strong and the method is suitable only with non-metallic pipes where the shielding effect is small. The second produces a more powerful modulated magnetic field by means of a rotating magnet and is for use in ferrous metal pipes.

Numerical Solution Methods have Advantages

THERE is little doubt that many of the systems of ordinary and partial differential equations arising in the mathematical description of chemical engineering processes defy analytical solution unless quite unrealistic simplifications are made. Thus direct solution by numerical techniques has much to recommend it. Even when an analytical solution is available it is often so complex that to interpret it would take as much numerical work as the direct numerical solution.

A recent paper* is testament to these remarks. It deals with an exothermic fixed bed catalytic reactor the reaction being first order with the usual Arrhenius relation connecting temperature and rate constant. Heat is removed from the outside wall of the reactor.

By use of enthalpy and material balances (some simplifying assumptions, e.g. flat velocity profile and no longitudinal diffusion are made) the equations describing temperature and concentration variation both radially and axially throughout the reactor are written down. These equations form a pair of non-linear second order partial differential equations with appropriate boundary conditions, the non-linearity arising from the exponential dependence of reaction rate on temperature.

No general analytical solution is known but for zero activation energy one of the equations admits a simple solution which on substitution in the second equation enables it to be solved as an infinite series of Bessel functions. To evaluate a temperature it would be necessary to calculate about 30 terms of this series: a time consuming business.

On the other hand using the numerical approach in the general case a solution can be obtained to adequate accuracy (10 x 10 points) in about 12 minutes on an I.B.M. 650 computer. The finite difference scheme used was the

implicit Crank-Nicholson technique; since with this method convergence is independent of the relative sizes of the radial and axial increments, the truncation error is second order and the non-linear term can be dealt with. For details of how the finite difference equations are set up and linearised without affecting the convergence and the boundary conditions the paper must be consulted.

The study was carried out as an aid to pilot plant design and to help in interpreting the pilot plant results. Although experimental results were not available for comparison with the numerical results some useful general conclusions about the design were obtained.

The interested reader may like to compare this paper with the much fuller treatise on fixed bed converters by Kjoar†.

* D. U. von Rosenberg, P. L. Durrill, E. H. Spencer, "Numerical solution of partial differential equations representing fixed bed reactions."

† J. Kjoar, "Measurement and calculation of temperature and conversion in fixed bed catalytic reactors" (Jul. Gjellerups Forlag-Copenhagen, 1958).

Heat Transfer between Fluids and Solid Particles

THE measurement of heat transfer coefficients for fluids flowing through porous solids or beds of solid particles is a matter of considerable importance in a number of processes. However, the direct measurement of heat transfer coefficients in such cases is difficult because the amount of heat transferred within the matrix, and the temperatures of the solid surface and of the fluid throughout the matrix, must be measured.

In the N.E.L. apparatus which has been referred to previously in this column the inlet temperature of air passing through the matrix is varied sinusoidally so that heat is transferred to and from the matrix itself. The heat transfer coefficient can be determined from a mathematical relation embracing the amplitudes of the inlet and outlet temperatures. This apparatus, we now learn, is working satisfactorily and has already been used for measuring coefficients for beds of steel spheres. It is evident that the new apparatus has great possibilities in the field of regenerator design.

Another type of exchanger which is surrounded in a certain amount of mystery, the plate heat exchanger, has also been further investigated at N.E.L. and while no detailed information appears to be at present available, the Laboratory reports that some differences in coefficients for various plates can be ascribed to differences in flow conditions. They have also explained the scatter of results obtained with some plate heat exchangers.

N.E.L. Annual Report 1960. Page 22.

Level Indicator and Flow Meter from N.E.L.

AN accuracy of 0.01 in. has been obtained with a liquid level detector which promises to be useful in the chemical industry; the use of two detectors fitted at different levels in a calibrated vertical tank together with an electronic timer also provides a simple form of flow meter.

The instrument relies upon the fact that the critical angle of methacrylate—which is used in its construction—to air is 42° but changes appreciably when in contact with a liquid. The detector is made of a 'U' shape methacrylate light guide with its closed end cut at 45° to the axis. A light source is fitted at one of the opening and at the other there is a photo-transistor. When the detecting end is in air, light from the lamp is reflected back to the photo element. When the liquid reaches the level of the detecting surface the light is no longer reflected back because the critical angle becomes greater than 45°. As a result the current for actuating an electronic circuit is interrupted, followed by appropriate alarm or control action.

N.E.L. Annual Report 1960. Page 22.

Electrolytic Sewage Purification

AN electrolytic process* which largely depends on the presence of magnesium salts in sea water, has been developed in Norway for purifying sewage discharged into the sea. It is claimed that the process will almost entirely eliminate phosphorous and organic matter.

Sewage is mixed with sea water and electrolysed. During electrolysis, phosphates are precipitated as insoluble magnesium-ammonium salts together with magnesium hydroxide. The hydroxide is formed as floccules with a high absorbent capacity for sludge. The hydrogen bubbles, which are liberated at the cathode, flotate the sludge and insoluble magnesium salts to the surface where they are removed.

The chloride which is liberated at the anode redissolves in the sea water and so helps to disinfect the effluent.

The most suitable design which has been developed for large-scale processing is an electrolytic cell with horizontal electrodes and without diaphragms. The power consumed is about 1 kwh per cu m of sewage, and the residence time somewhat less than one hour.

* Invented by DR. ERNEST FOYN; Exploited by Elektrokemisk A/S, Oslo Norway. Digested from European Technical Digest, September 1961.

Cold and Vacuum by Vortex

A DEVICE of more than marginal interest to chemical engineers is that technical curiosity, the vortex tube, first developed by the French metallurgist, RANQUE, around 1930. It consists of no more than a cylindrical tube to which air or other compressed gas is admitted tangentially. One end terminates in a valve, whereas downstream of the inlet is fitted a diaphragm. By means of this simple device it is possible to divide an injected gas stream into hot and cold portions, the temperature and the amount of the cold fraction being determined by the setting of the valve.

With the passage of time the mechanical simplicity of the apparatus has encouraged attempts to improve its performance as a producer of cold. HILSCH, some fifteen years later, for example, determined the dimensions giving the highest efficiency, and pointed out at the same time, that its apparent low efficiency would limit its field of application.

Since then Soviet investigators have given considerable attention to the device and have produced a number of variations in design, including multi-entry tangential nozzles, culminating with the evolution of what is called the short vortex tube. Previous models suffered from a number of disadvantages apart from the inherent low coefficient of performance. They required accurate workmanship and any deviation from tangential entry resulted in poor performance. Moreover, the internal surface finish is very important and roughness causes performance to deteriorate sharply. Finally, the diaphragm has to be changed whenever maximum cold is required instead of maximum temperature drop.

The short vortex tube described in a recent article* overcomes these shortcomings without any loss of performance. Summarizing, one can say that the coefficient of performance is on the low side, of the order of 0.15 to 0.2, and the maximum temperature drop is about 50 per cent of the adiabatic. Despite this, the tube has a number of advantages apart from its simplicity and absence of moving parts. It is quick in action and requires but the simplest means of control. For this reason it has already been used as a producer of cold and would seem to have process possibilities. The fact that Shell Laboratories have been using the tube for process work since 1950 suggests that more will be heard about this device in the future; and its ability to produce vacua as low as 20 mm Hg abs. should also not be overlooked.

* B. B. PARULEKAR, *Journal of Refrigeration*, 1961, 4 (4), 74.

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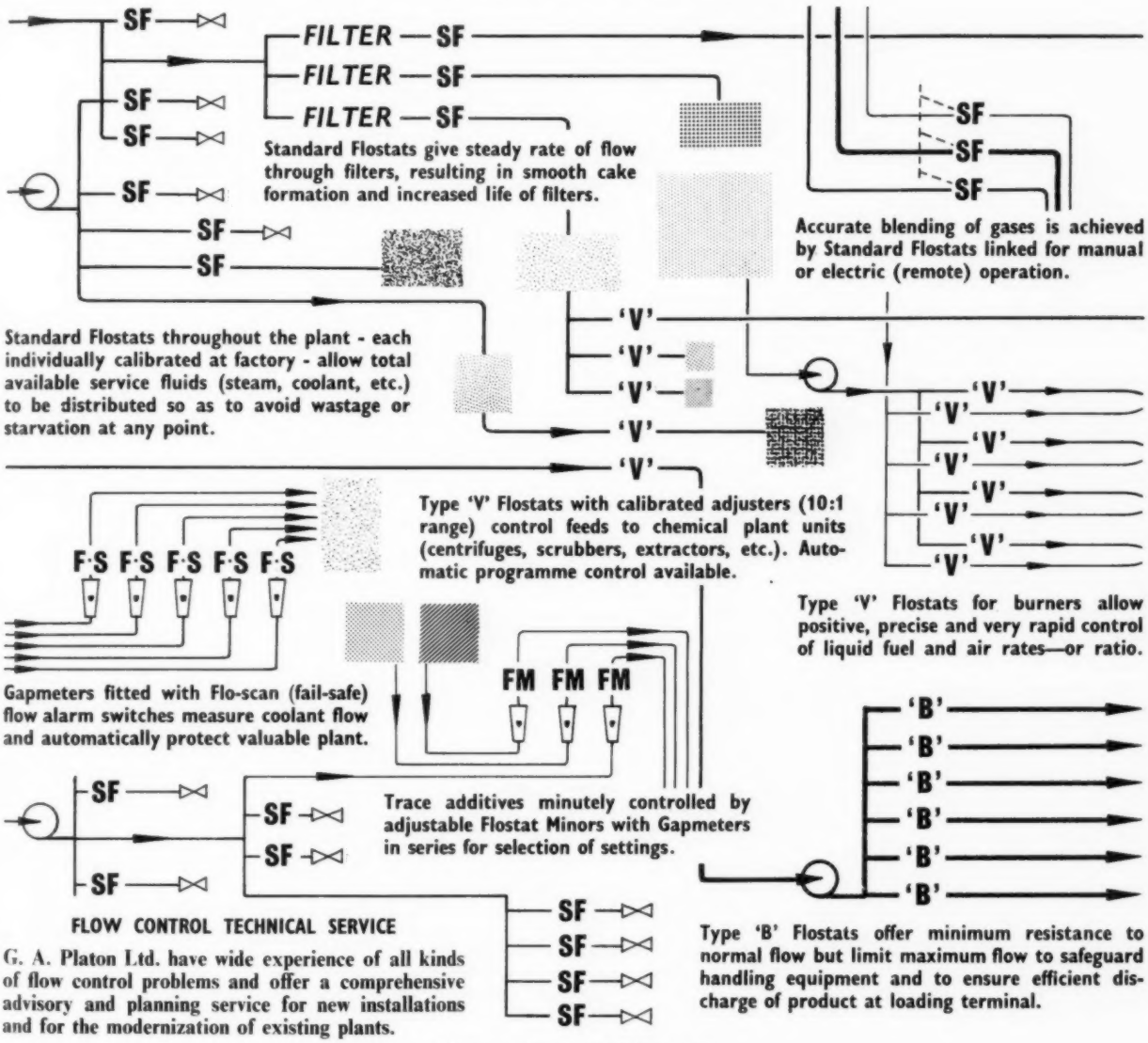
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Magnetic Fields for Crystallisation

THE possibility of speeding up crystallisation involving difficult-to-crystallise solutions, for example those of very low concentration, and solutions of partially soluble solids is suggested by a recent Polish research.* In this work, upon solutions of $KBrO_3$, $HgCl_2$ and H_3BO_3, which were cooled from 30°C to 27°C, electromagnetic fields of intensity 500-2,000 ampere turns were applied to the solutions. The results showed that it is possible to reduce considerably the induction time which elapses before crystallisation commences. In the case of boric acid solutions a reduction from 7 minutes to less than 1 minute proved to be attainable.

The investigation revealed a number of factors affecting the induction period. For example, it has a limiting value which is reached when the electromagnetic field is applied over a long period, and this limiting value becomes the smaller the greater the strength of the field. Increase of temperature, too, reduces the induction time, and mechanical factors such as shock, vibration and ultrasound when superimposed upon the electromagnetic field also reduce the period.

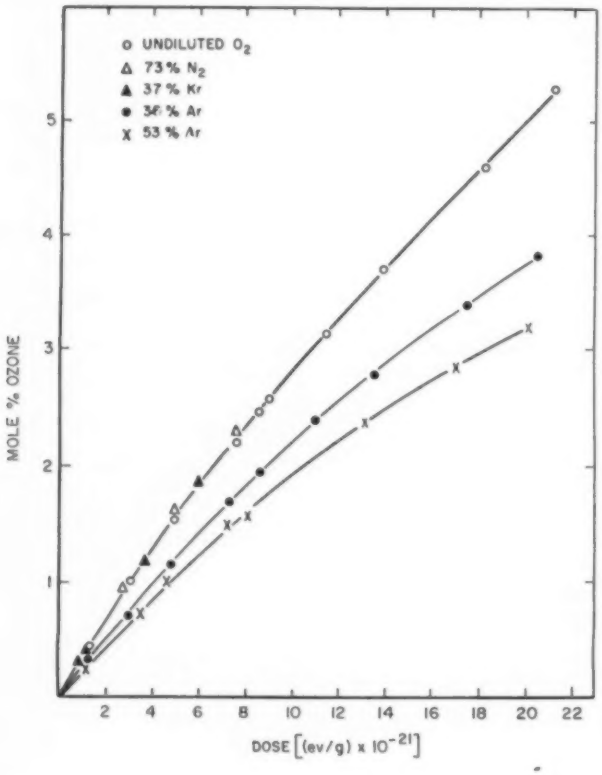
* S. Weychert and J. Luczak, *Chemia Stosowana*, (1961) 2, 195

Ozone Formation by γ- Radiation

IRRADIATION, particularly by gamma rays, has been studied as a means of promoting several chemical reactions, one of the most studied being chlorination of benzene to give gammexane with a high content of active isomer. Now ozone formation from oxygen is also being studied as a possible alternative reaction.

A study *of the yield of ozone in several liquid and solid oxygen mixtures, as a function of γ- irradiation dose, has shown that inert diluents such as argon, krypton and nitrogen do not decrease the yield. This suggests that the energy absorbed from the γ- radiation is transferred from the diluents to the oxygen.

For the irradiation, about 0.3 mole of sample was sealed in a pyrex ampoule which was placed in a Dewar flask containing an appropriate coolant. Liquid oxygen at 90°K, liquid nitrogen at 77°K and liquid helium at 42°K were the diluents used, and the samples were irradiated with a cobalt-60 source shielded by water. After the irradiation, the ozone content was determined by chemical or by dilatometric methods, the latter being preferred.



To determine the effect of dilution and energy on the yield of ozone, oxygen was mixed with argon, krypton and nitrogen respectively. Neither argon nor krypton can form stable compounds with oxygen. Some nitrogen dioxide is formed in the presence of nitrogen, but the yield of ozone should be reduced because less energy is absorbed by oxygen.

The results in the presence of nitrogen have practical application for low temperature experiments where liquid nitrogen is used to cool samples during irradiation. Commercial liquid nitrogen may contain several per cent oxygen. Even pure nitrogen condenses oxygen from the air. The Bureau has found that the amount of ozone formed during irradiation of liquid nitrogen is disproportionately high considering the low oxygen content. If divided or reactive organic material, such as polystyrene foam or rubber, are soaked in irradiated liquid nitrogen they will ignite when lifted from the liquid. The ozone becomes concentrated when the nitrogen is evaporated and the amount of ozone is apparently sufficient to cause ignition. Because liquid ozone can explode even when no organic matter is present, irradiated liquid nitrogen should not be permitted to evaporate completely from its container, as a precautionary measure.

*D. W. Brown and C. A. Wall, National Bureau of Standards.

Lyapunov Functions

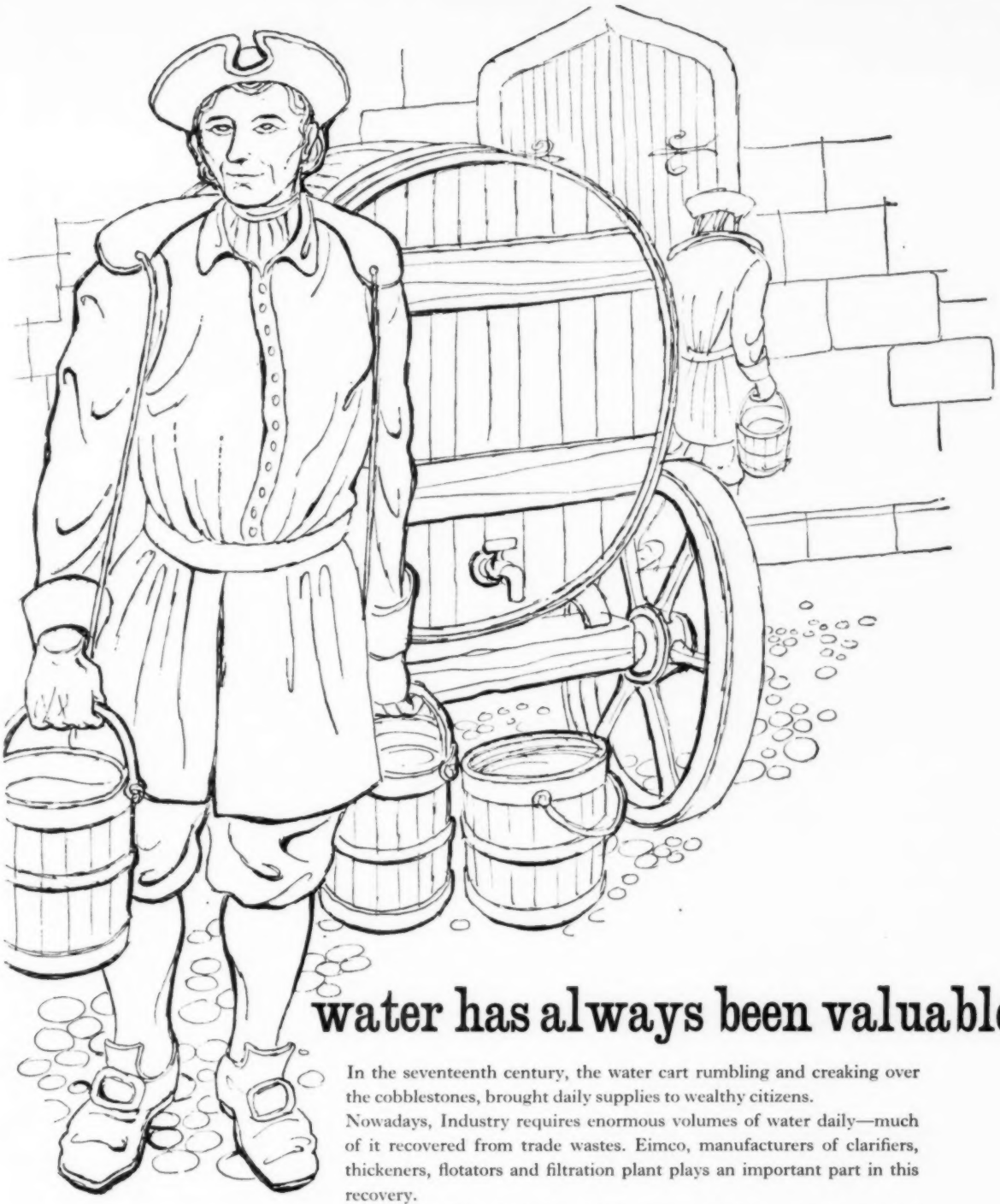
UNFORTUNATELY many mathematical techniques of interest to the chemical engineer appear in journals that he does not normally see. An example of this is the investigation of the stability of a steady state of a dynamic system by the "direct" or "second" method of Lyapunov. Most of the work on this subject has appeared in Russian journals (a few of which have become available recently in an English translation) or in American electrical and control engineering publications.

Lyapunov first developed his method in 1892. It is essentially a generalisation of Lagrange's theorem concerning the signs of the potential energy and its derivative in the stability of equilibrium of a mechanical system. Thus he showed that a system is stable if a function, the "Lyapunov function", can be found which exhibits certain characteristics with regard to its sign and that of its derivative. An important aspect of the method is that it allows stability to be investigated without having to solve the equations of the system. Its main drawback is the failure, up to the present, to find a set of rules for obtaining a Lyapunov function for a general non-linear system.

Many workers in Russia and in America (to a lesser extent) have extended Lyapunov's method particularly in the field of analytical dynamics and automatic control theory. In 1936 Chetaev pointed out that in physical and chemical systems obeying the 2nd law of thermodynamics the difference between the entropy and its maximum value may be regarded as a Lyapunov function. He also put the method to use in investigating the stability of aircraft and the stability of numerical methods for the integration of differential equations.

More recently Lyapunov functions have been used in ensuring the stability of optimal control systems. It has also been suggested that a means of obtaining stable optimal control is to make a suitable Lyapunov function of the system decrease at a maximum rate.

As previously mentioned a basic difficulty of the method is the lack of a systematic technique for finding a Lyapunov function for a given system. Another drawback is that it is only



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concerned with small disturbances from the steady state. In a recent article* INGWERSON has shown how the method may be extended to deal with finite disturbances and has developed a means of producing Lyapunov functions for non-linear systems from a modification of known functions for linear systems. As he points out his method is not completely formal and will not always yield satisfactory results but it does restrict the amount of guesswork involved in finding Lyapunov functions in the non-linear case.

A brief, readable, general introduction to Lyapunov's second method is given in the proceedings of a conference held by the A.I.E.E. in 1960.†

* INGWERSON, D. R., "A modified Lyapunov method for non-linear stability analysis," *Trans. A.I.R.E.* AC-6, 2, 199 (1961).

† KAZDA, L. F., editor, "Work session in Lyapunov's second method," Ann Arbor, Michigan (1960).

Sulphur Dioxide Pollution

COMMENTING on the contribution of industry to clean air, a speaker at the Clean Air Conference* emphasises what is now generally recognised; that while the air is cleaner in regard to solid pollutants the sulphur dioxide level tends to increase. So far it appears that the most practical means of reducing pollution from this source at ground level is to discharge the sulphurous gases hot and dry at a high level, a respect in which industry, naturally enough, is more effective than the individual householder.

All the more useful, therefore, are the recommendations contained in this paper on the design of chimneys, some of which have already been published. For example, in the case of small industrial plants, for boilers in the range 5000-33,000 lb/h. the minimum recommended height is 60 ft. This height should increase with boiler capacity, in steps of 20 ft, up to 120 ft in accordance with a curve with a slope designed to give a constant low maximum ground level concentration of SO_2 and rate of dust deposited, for undisturbed air flow. These recommendations require that the maximum rate of deposit of grit and dust from the discharge should not exceed 1000 g/100m^2 per month and that the chimney top is not seriously affected by down-draughts.

For capacities over 33,000 lb/h. the minimum recommended height is either greater than 120 ft., or two-and-a-half times the height of the adjacent building, whichever is the greater. In cases where the two-and-a-half times recommendation proves to be excessively expensive, it is suggested that the height and position of the chimney should be determined by wind tunnel tests.

* Paper read to the Clean Air Conference, 1961, Brighton, by W. J. DICKIE 'Manufacturing Industry and the Clean Air Act."

SO_2 Pollution—Measures for Its Removal

IN the German Federal Republic one hears of a number of interesting processes for tackling the problem of SO_2 pollution, virtually at source. One successful process has been to pass the flue gases containing the sulphur dioxide through a special chamber containing a catalyst, the temperature of the operation being around 350° C. The sulphur dioxide is absorbed and the gases cleaned of solid particles. The process, however, is costly and its economy depends a great deal on the possibility of selling the recovered sulphur.

A further process attracting attention, consists of blowing basic material into a combustion chamber, in a manner similar to that of dolomite injection. The basic material is mixed with a cheap catalyst, which oxidizes SO_2 to SO_3 and, under the conditions in the combustion chamber, this latter reacts at once with the basic material to form sulphate. Operating and investment costs are both low, and first estimates are that no more than 5 DM are required per ton of fuel oil burned.

"Smokeless Air," Journal of the National Society for Clean Air, No. 119, Autumn, 1961, p. 33-34.

Stress-Corrosion Cracks

MAKING its debut in August, the new international journal "Corrosion Science," published by the Pergamon Press Ltd., under the auspices of the Corrosion Science Society and the Centre Belge de l'Etude de la Corrosion, contains two papers on the mechanism of stress corrosion by DR. J. G. HINES of the Billingham Division of I.C.I. Ltd.

Discussing the development of stress-corrosion cracks in austenitic chromium-nickel steels, DR. HINES has found that the life of an axially-stressed cylindrical specimen in hot concentrated chloride solution can be divided into an induction period and a period of crack propagation:—the latter itself being divided into two stages. The second stage of crack propagation is accompanied by a fall in potential and by accelerating extension, but no detectable change in potential or extension rate occurs during the first stage. However, sufficient corrosion current is available to account for both stages of crack formation by purely electrochemical processes. The duration of the induction period is mainly controlled by alloy composition and applied stress, the effect of stress depending on the metallurgical condition of the alloy. It is also sensitive to environment. The duration of the second stage of crack propagation depends on specimen size as well as on the mode of stressing, while the duration of the first stage is very sensitive to applied stress, the metallurgical condition of the alloy and specimen size or form. The induction period is the most satisfactory measure of the resistance of an alloy, but with direct axially loaded specimens the time to fracture—much easier to measure—is also a reasonable criterion.

Reviewing mechanisms which have been proposed for the propogation of stress corrosion cracks DR. HINES concludes that stress corrosion cracks can be formed only if the rate of penetration of the tip is much greater than the rate of attack on the crack sides and the rest of the surface. Electrochemical mechanism provides the simplest and most satisfactory explanation. In the case of the austenitic chromium nickel steels in chloride solution, most of the known facts concerning crack development can be explained in terms of electrochemical crack propagation in which the attack is concentrated at the crack tip because the activation polarisation for anodic dissolution is reduced by yielding.

Statistical Tools for Engineers

SIX useful, simple and speedy statistical "tools" for the evaluation of ideas from operating and experimental data have been put forward by B. S. BROWN* of E. I. du Pont de Nemours & Co. Of wide application, the tests require the memorising of only simple counting procedures plus three "magic" numbers (significance levels)—2, 7 and 11. The techniques used make no assumption about the specific distributions from which data are drawn.

The techniques fall into two groups—tests and estimates. The tests give a "yes" or "no" answer to the question "is this idea reasonable?" The estimates provide a guess at the value of a number, or parameter that summarises and describes the data. Normally the estimate would only be used if a test had indicated that the data was in fact of interest. The tests are keyed to a 5 per cent level of significance.

The outside count test is used to decide which of two ways of doing something is better or whether two items are similar or different. A useful feature of this test is that the two sample sizes need not be equal; but they must be within about 25 per cent of each other.

The sign test can be used whenever the data can be divided naturally into two mutually exclusive groups, A and B, the data being compared in pairs and assigned plus or minus values according to whether the A value of the pair is better

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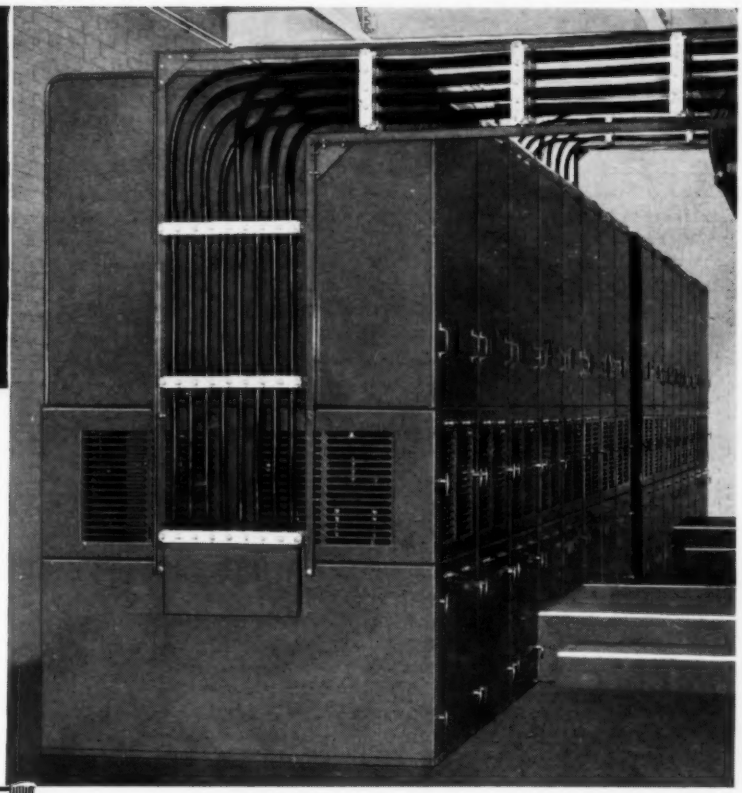

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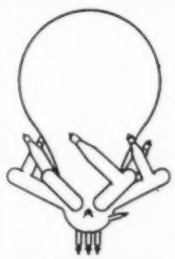

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than B or vice-versa. The plus and minus signs are counted, subtracted from (D) and added together (N). If the absolute value of D is greater than $2\sqrt{N}$, then there is a difference between A and B at the 5 per cent level of significance.

The corner count test is used to judge suspected correlations in a scatter plot.

The two-point estimate of the mean is a quick method for determining the mean from a set of values. Often the computation can be done mentally. For very small samples (five or less) the arithmetic mean of the smallest and largest values gives the "midrange." For samples of between six and 20 values, the mean is taken as the arithmetic mean of the third-largest and third-smallest values.

Quick estimate of standard deviation—the measure of sample variability—can be obtained for small samples from the "range," that is, the difference between the largest and smallest items in the sample. For samples of less than 12 items, range is approximately equal to the standard deviation × the square root of sample size. For larger samples, the sample is divided randomly into several groups of equal size between six and ten. The range for each sample group is obtained, the ranges are summed and the sum is then divided by the number of groups and by the square root of the group size; this gives an estimate of the standard deviation of the entire sample.

The straight line of best fit is a graphical method of determining the straight line that best expresses a correlation between two variables in a scatter plot, by making use of the median.

* *Chemical Engineering*, September, 1961, p. 137.

Controlling Evaporation From Lakes

GROWING water shortages in the western states of the U.S.A. have been accentuated by drought this year.* To combat the problem, the U.S. Bureau of Reclamation is sponsoring studies of the control of evaporation by spreading chemicals on the water surface. A mixture of cetyl alcohol and stearyl alcohol is one of the more commonly-used compounds used as a barrier against evaporation.

In Utah state, where the drought has caused a critical situation, light aircraft have been used to spread the chemicals. The results of a test programme are now being studied; early results suggest that substantial savings can be made.

In California, at Lake Cachume, extensive tests are being carried out by the Bureau of Reclamation. A dozen rafts around the lake carry 50 gallon containers holding a mixture of water, the alcohol compound and compressed gas. A butane-fueled heater unit heats the mixture; as the gas expands it forces the chemical mixture through a valve on to the surface of the water. The valve is timed to open periodically, but the amount of valve opening is controlled electrically by wind gauges. Windspeeds higher than 6 m.p.h. are required for effective distribution of the chemicals.

The cost of evaporation control has been reduced from 61 dollars per acre-foot in early tests near Oklahoma City to about 12 dollars an acre-foot in the Utah test programme. It is hoped to reduce costs still further by substituting less expensive chemicals for the alcohol compounds now commonly used. For companies at Lake Cachume, water is valued at 25 dollars an acre-foot for irrigation purposes and 35 dollars an acre-foot for domestic use.

* *Wall Street Journal*, July 9, 1961.

Desulphurizating Coke with Metallic Sodium

ANOTHER application of the fluidized bed technique has been found—in the desulphurization of coke-oven light oils with metallic sodium.* The sodium reacts with thiophene and other sulphur compounds to form sodium sulphide, and gives a benzene fraction, a benzene-toluene cut, or a benzene-toluene-xylene cut with a thiophene content below 1 p.p.m.

Two relatively simple sodium sulphur-removal processes have been developed for benzene toluene xylene purification —one, for smaller capacity plants, utilises a mechanically agitated system. The other process, recommended for coke-oven plants with a capacity of over 10,000 gallons a day of light oil, uses a fluidized solids system. Both processes have been operated on a pilot plant scale. The total direct operating costs are: with a plant capacity of 10,000 gallons of light oil a day, using the mechanically agitated process, 1.55 cents per gallon; with a plant capacity of 30,000 gallons of light oil a day, using the fluidized solids process, 0.86 cents per gallon. Estimated capital outlays are approximately 200,000 dollars for the 10,000 gallon plant, 350,000 dollars for the 30,000 gallon plant.

For the treatment of napthene, sodium is metered directly to the reaction kettle; in this case the investment cost for desulphurizing 10 million lb. per year is 50,000 dollars, and the operating cost 0.57 cents per lb. Corresponding figures for a 50 million lb. per year plant would be 100,000 dollars outlay and 0.43 cents per lb. operating costs.

* *Petroleum Refiner*, August, 1961, 127.

DIARY

The Institution of Chemical Engineers

November 7 South-Eastern Branch, The Geological Society, Burlington House, Piccadilly, London, W.1, at **5.30 p.m.** "Underground gasification of coal", by F. E. WARNER, J. SZEKELY and R. S. H. MAH.

November 14 North Western Branch, Manchester College of Science and Technology, Jackson Street, Manchester, at **4.30 p.m.** "Chemical Reaction Engineering", two papers by K. G. DENBIGH and one other.

November 15 Midlands Branch, Midland Hotel, Stephenson Place, Birmingham 1, at **6.30 p.m.** "Some performance data on a new tray column", by MAX LEVA.

November 24 Scottish Branch, Lea Park Tea Rooms, Falkirk, at **7.30 p.m.** "Absorption on the surface of a sphere", by G. STEWART. "Heat transfer in boiling", by R. GRAY.

Institution of Mechanical Engineers

Meetings to be held at 1 Birdcage Walk, S.W.1.

October 25 Presidential Address: "Co-ordination of Engineering Research and the Conservation of Scientific and Technical Manpower", by SIR KENNETH HAGUE.

October 30 Thermodynamics and Fluid Mechanics Group. "The Extent to which the Institution should contribute to the Availability of Design Data and Information in Thermodynamics and Fluid Mechanics."

Colloquia at the University of Leeds

October 27 "The development and testing of a novel oriented packing for vapour-liquid contacting", by PROF. G. G. HASELDEN.

November 10 "Deviations from the Arrhenius equation", by DR. J. R. HULETT.

Society of Chemical Industry

November 3 The Royal College of Science and Technology, Glasgow, at **7.15 p.m.** Jubilee Memorial Lecture: "The Organisation of Research and Development", by DR. F. ROFFEY.

November 6 14 Belgrave Square, London, S.W.1, at **6.30 p.m.** "The U.K.A.E.A. and its Relations with Industry", by DR. N. GOODWAY.

November 6-8 The C.I.C. Canadian Chemical Engineering Conference will be held at Royal York Hotel, Toronto.

November 27-December 1 The 28th Exposition of Chemical Industries will be held at the New York Coliseum.

INTERNATIONAL CHEMICAL ENGINEERING CONGRESS FOR BRNO

THE first international congress on chemical engineering, chemical equipment design and manufacture and automation to be held in Czechoslovakia will take place in Brno on September 3rd-8th, 1962.

In their preliminary announcement the organisers indicate that they would like the following fields to be covered in the section dealing with chemical engineering—flow characteristics in chemical equipment; turbulent flow of non-Newtonic fluids; mixing. Flow characteristics in heterogenous systems: liquid-granulated solids, gas-liquid, liquid-liquid; mixing. Heat exchange in chemical equipment; heat conduction and radiation in furnaces; laminar and turbulent heat transfer by convection. Heat transfer in mixing non-Newtonic and heterogeneous liquids, problems of heat exchanger design and evaporator. Mass transfer in chemical equipment, laminar and turbulent mass transfer by convection, and mass transfer in heterogeneous systems. Separation processes such as distillation, absorption, extraction, and ion-exchange. Homogeneous and heterogeneous reactors, catalytic reactors, reactors stability.

In the section devoted to chemical machinery design and fabrication the following subjects have been put forward—stability and strength calculation methods. Calculation of shell structures. Pressure vessels for high and low temperatures. Problems of three-axial stresses and of homogeneous material properties: stress characteristics in tube-sheets. Problems of structural materials: use of newly developed steels having high mechanical properties; the economics of special alloy use in vessels. Manufacturing technology: Welding of high-strength steels (manual welding, automatic submerged arc welding, electro-slag welding). Heat treatment (e.g. rapid castling annealing, annealing of tube-bands welded to tube-sheets).

Finally, the Automation section will cover—instrumentation, measuring and regulation systems, automatic data scanning and handling in chemical process control, economic problems of process control optimization.

The following preliminary programme has been arranged—

September 3rd, 1962— am Opening ceremony at the Janacek Opera House.
pm First Sessions of Congress Sections.
Reception at the Town Hall by the Mayor of Brno.

September 4th, 1962— am Section Sessions. Principal, Lecture. Short Reports.
pm Discussion

September 5th, 1962— am Sessions—Lecture—Discussion.
pm Discussion.

September 6th, 1962 —am Sessions—Lecture Discussion. Evaluation of the work done by Sections.
pm Departure for Slowakia—a short trip.

September 7th, 1962— am Visiting a chemical plant.
pm Return to Brno.

September 8th, 1962— am Plenary Session. Evaluation and Closing of the Congress Proceeding. Official closing ceremony of the 1st Congress of CHISA.
pm Attending the opening ceremony of the 4th International Trade Fair, Brno 1962.

Special visits will be arranged to leading industrial factories for interested parties. Free evenings are reserved for attending social gatherings, cultural programmes, etc. in accordance with the wishes and tastes of the participants.

The official languages of the Congress are Czech, English, German and Russian. Participants are kindly requested to select one of the official languages for their lectures and contributions. The principal lectures, short reports and discussion contributions will be delivered in one of the official languages and simultaneously interpreted into the other three official languages. The number of discussion contributions will depend on time available. Papers will be published unabridged in the Congress Proceedings and short summary (not exceeding 250 words) will be published in all the four official languages. Participants are kindly requested to submit their papers and summaries by March 15th, 1962, at the latest. Papers received later will not be published in the Congress proceedings.

Further details from:—

Organising Committee for the first International CHISA Congress 1962, Vystaviste 1, Brno, C.S.S.R.

PROFESSIONAL APPOINTMENTS

BRADFORD INSTITUTE OF TECHNOLOGY

Applications are invited for the following posts:-

LECTURER IN CHEMICAL ENGINEERING

Arising from the continued expansion of the Diploma in Technology course in Chemical Engineering, further additions to the existing academic staff are required. Candidates (either male or female) should have industrial experience of a type that can contribute to the overall development of the Department and to further teaching specialisation, e.g. work in instrumentation and automatic control, computer programming, project design, low temperature engineering.

RESEARCH ASSISTANTS

(3 posts, male or female)

To further the rapid development of research work that has already taken place in the cryogenic and computer and other fields, further research assistants are required. Minimum qualifications required will be Graduate Membership of the Institution of Chemical Engineers or equivalent (i.e. recent university graduates will be considered).

Salary Scales: Lecturer £1,370-£1,550 per annum. Research Assistant £520-£1,000 (plus training and graduate allowances).
Previous industrial and research experience, at a suitable level, will be taken into account in fixing the commencing salary.

Further particulars and forms of application may be obtained from the Registrar, Bradford Institute of Technology, Bradford, 7.

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Technical Writer Required

Applications for a technical writer who will be resident in Milan, the applicants must be capable of taking charge of the technical publications of a large Italian company. The duties will include assistance in the preparation of tenders and equipment specifications. A very high salary is offered for this interesting post.
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Graesser Salicylates Ltd. Chemical Manufacturers, Sandycroft, near Chester require a Development Engineer with experience in chemical plant erection, operation and maintenance. Applicants must hold an honours degree in Chemical Engineering or an equivalent qualification. Good prospects. The Company operates a non-contributory Pension Scheme. Please apply in writing to The Managing Director.

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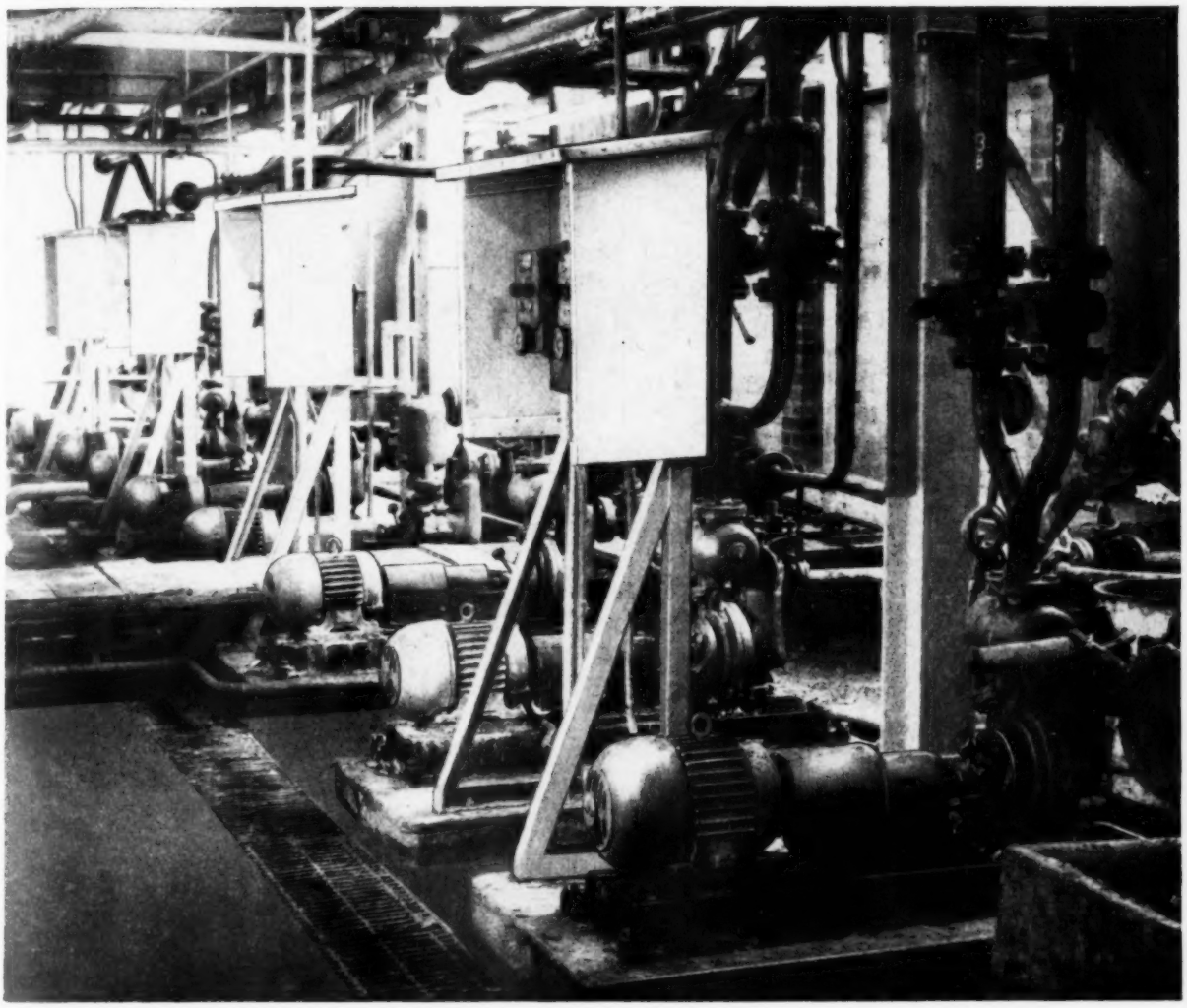

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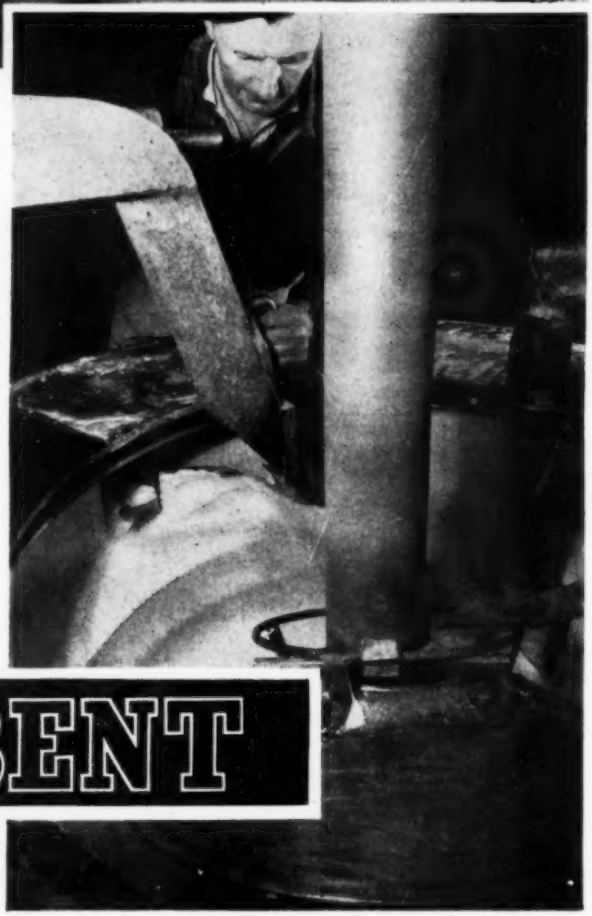

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Design — Time for Rationalization

OF all the functions of the engineer, design remains the most undisciplined, the least perfectly understood. Designers are, in the main, haphazardly trained, acquiring their experience by the painful process of applying to design problems the practical knowledge gained on the plant or shop floor. Meanwhile, the increasing complexity of plants and processes leads to ever larger and more unwieldy design teams. No design team is likely to be truly efficient until the process of design has been thoroughly dissected and its anatomy clearly understood.

There is a growing recognition, particularly in mechanical engineering, that a fundamental approach to design can result in the formulation of principles which will be of far-reaching value in training engineering designers of the future. A recent research on process plant design, carried out in the Engineering Department of Cambridge University, led D. L. MARPLES[1] to conclude that

> "designing consists of a sequence of critical decisions leading from the initial statement of the problem to the final specification of the "hardware". Each decision involves the consideration of various proposals; predictions of the outcomes of each with particular emphasis on the sub-problems raised by it and an evaluation of the outcomes in terms of criteria stemming from the natural properties of the materials involved; engineering values; prior decisions and the judged tractability of the unassessed portions of the design.
>
> The examination of proposals may be conducted serially or in parallel. . . .
>
> Novel ideas for solutions appear to be obtained from trying to solve the problem using well-established methods and then finding new ways of solving the sub-problems revealed. There was little evidence of the use of intuitive flair."

The last point, it may be noted, appears to dismiss the popular image of the designer as an individual with a special intuitive gift which cannot be imparted by formal training. A critic of the suggestion that design, like music, is an intuitive gift, pointed out that, while this might be so in a few cases, music lessons were common and—although but a few geniuses emerged—produced many competent musicians who formed the backbone of music. This was what was wanted: to teach design and so develop competent designers along with the occasional "natural" genius.

It is interesting to extend the analogy further by considering that musicians are taught the same principles whether they play the reed organ or the violin: might it not be possible to discover the common principles underlying all engineering design, no matter in what field it is applied? Already we have seen, in chemical engineering, a move away from the "unit operations" concept, with the appreciation that a common principle underlies a number of outwardly dissimilar operations. It seems inevitable that a unified approach to all engineering design problems will eventually emerge.

Before this can be brought about, however, much effort is needed to provide case histories ranging over a wide field of industrial plant and processes. Apart from its value in research and in training, such a fund of knowledge, made generally available, would have a practical value in minimizing the expenditure of effort on design problems for which standard solutions exist in other fields of engineering.

Possession of a common fund of design solutions would also lead to a much more extensive use of electronic computers as an aid to design, quite apart from their use in handling mathematical problems. If design can be regarded as a synthesis achieved by the progressive selection and processing of established ideas, there seems no reason why such ideas might not eventually be presented to a computer in the form of a programme. The use of a computer, in the initial stages of design at least, would save much time.

Time, indeed, has an influence on designing the far-reaching effects of which are not generally appreciated. As our contemporary, *Engineering Materials and Design*, has pointed out, "time not only presses incessantly as a whole, but such things as development time, procurement time, etc., are often criteria which discriminate against otherwise perfect solutions". It is obvious from this that rationalization of design would lead not only to the speedier and more efficient realization of projects, but also to better designs.

Support is lent to this conclusion by a recent paper[2] which discusses in detail how mathematical, statistical and computational techniques have been applied to a variety of machine design problems with material benefits to the finished designs. It is pointed out that, despite the existence of these techniques, however, the present-day methods primarily augment the traditional, empirical approach to design. If the designer chooses an inherently poor system in the first place, optimization only helps him make the best of a bad situation. The greatest potential benefits lie in the direction of synthesis; that is, methods that proceed directly to the solution of a design problem. The next few years will show real progress in the development of such approaches.

REFERENCES

[1] MARPLES, D. L., "The Decisions of Engineering Design", *The Engineering Designer*, December 1960. Available from I.E.D., 38 Portland Place, London, W.1.

[2] LESTER, J. T., "Optimization in Equipment Design". In the press.

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FRESH WATER FROM THE OCEAN

The major processes of desalination by evaporation and freezing are reviewed. Of the processes, which in large plants can desalt water at a cost of 10-15 cents/tonne, an improvement over multiple flash evaporation, the vapour reheat process can evaporate some 16 lb of water lb steam, equivalent to a multistage evaporation of 15-20 effects. In this process there are no metallic heat transfer surfaces and no scaling problems, and there is but one boiling point elevation loss. The optimum forced-circulation vapour compression evaporation plant developed by Rolf Andersen is another whose performance is considered. Power costs for circulation pump and compression total 50 kWh/1000 U.S. gallons when 500-1000 times as much water is circulated as is evaporated. Finally the Umano (Japan) process is described and its economics examined

by
D. F. OTHMER

WATER is the most interesting and unusual material in the world! Physically, chemically and biologically it is unique—likewise industrially and politically. It has by far the widest range of prices of any material in commerce, from zero to almost infinity! It sells for less than one cent per 1000 gal for irrigation; 2 to 5 cents for industry; 20 to 60 cents for domestic use; and any necessary price for drinking! In tank cars it may cost $7 or $8 per 1000 gal. Potable water has been shipped from New York to South America and from England to Chile.

In the United States about 10 per cent of the surface flow is used. Supply is constant, but population grows and usage has climbed to unreasonable proportions. Irrigation and industry each use enormous quantities of water. It takes 20 tons of water to make a ton of sulphuric acid or to refine a ton of petroleum; 275 tons to make a ton of steel; many hundreds of tons to grow a ton of wheat, more for rice!

Agricultural water problems include prevention of seepage, distribution, and other losses in irrigation, better utilization by crops, prevention of transpiration from both ground and crops, seeding of clouds, utilization of dew, etc. These problems are not the mission of the chemical engineer; but they *must* be recognized by other scientists; and they require significant break-throughs in practice. Thus, irrigation water is usually hundreds or thousands of times the weight of the crop, and an even larger ratio to the chemical or physical water therein.

Per capita water usage is three times that of 1900. In some areas twice as much water is drawn from the ground as soaks in, with a yearly drop of 10 ft in the water table. Water is very unevenly distributed, with major shortages in some very populous areas, e.g., California. On average, the United States would balance water supply and increasing demand in about 15 years if all could be divided *equally*. Fifty million face shortages before then; desperate local shortages will come much sooner, and have already in dry years. In 1957, 1000 communities in 47 of the 48 continental states restricted water usage. In oil-rich Texas, people lined up to buy water—at twice the price of gasoline!

Many towns normally pump treated sewage back into the ground, and wells bring the water back up. In dry 1957 at least one town survived through complete re-use of its sewage. Some large cities use river water which has been through sewers up-stream on an average of 2.5-6.0 times. Two out of five U.S. cities have inadequate water supplies. Yet half the states, two-thirds of the industry and over half the population border on the limitless sea.

There is a tremendous urge for chemical engineers to provide processes and equipment to extract water from one-thirtieth as much salt in sea water, or one hundredth as much in brackish waters. Within 20 years over one hundred billion dollars will be spent in the United States for plants for desalinating water; this, averaging five billion dollars a year, is much greater than that spent for equipment by the chemical industries. Many more billions will go for plants for recovering water from sewage for immediate use or discharge to streams.

The greatest, although possibly not the most dramatic, engineering achievement of this next generation will probably be the development of processes and the building of plants for supplying *water*, the most unusual, but also the simplest and most abundant material. Water supply may be more important to the world than atomic energy; and it is certainly more important to the U.S.A. than a man on the moon!

Background of Processes

The Office of Saline Water (OSW) was organized eight years ago in recognition of the future shortage of water. OSW has stimulated much thought and activity in scanning the horizons of science; it has investigated scores of suggested processes. OSW has also been authorized to have designed, built and operated plants from about 250,000 gpd to 1 million gpd to use five different processes under different conditions. Hundreds of municipalities have claimed urgent need for one of these!

Dr. D. F. Othmer is Professor of Chemical Engineering at the Polytechnic Institute of Brooklyn, New York.
This article is based upon a paper presented at the 1961 Dechema-Achema Congress and is published with their permission.

The OSW has reduced the cost of fresh water from the sea in eight years from $5 for the 1000-year-old distillation process to $1 per 1000 gal, with a promise of 40 to 50 cents for the next generation of million-gallon-a-day plants. However, there is no hope for water at 1 to 2 cents, the maximum for irrigation by present wasteful utilization.

In large aqueducts, water is transported for from 5 to 15 cents per 1000 gal per 100 miles. Feather River will supply Los Angeles in the world's largest water project. This three billion dollar system will bring water 750 miles, over 4000-ft-high mountains, for about 50 cents per 1000 gal, including all capital and other charges. Conversion of adjacent sea water would cost now about 45 cents, and only a part of the tremendous cost would need to be invested in the first 20 years, since entire capacity is not immediately needed. Future additions would give lower cost if desalination processes improve.[2] But desalination is not quite mature technically; and the chemical engineer cannot yet compete with the civil engineer on the political problems of so huge an investment.

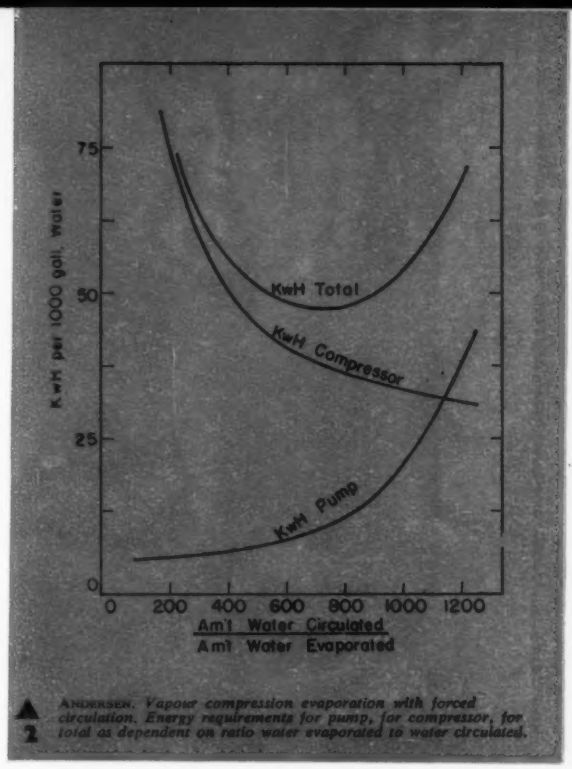
Water meters are needed to reduce the tremendous waste of unmetered city water. In ancient Rome one-third of the private connections were illegal to avoid water taxes; but wasted water may be an even higher fraction when there is no meter; and aqueducts must push scores or hundreds of miles farther to bring water to be wasted in the cities!

Chemical engineering has made possible a solution for some coastal cities, as is usual on board ship. In towns by the sea, fresh water should be circulated in one pipe system for potable use, while sea water circulates in another system for sanitary and many industrial uses, washing, bathing, etc. If desalinated water costs possibly ten times as much as treated sea water, extensive usage of salt water would result. Chemical industry makes this possible through (a) synthetic detergents which allow washing and bathing in saline water; (b) cheap plastic pipes and fittings which withstand corrosion of sea water.

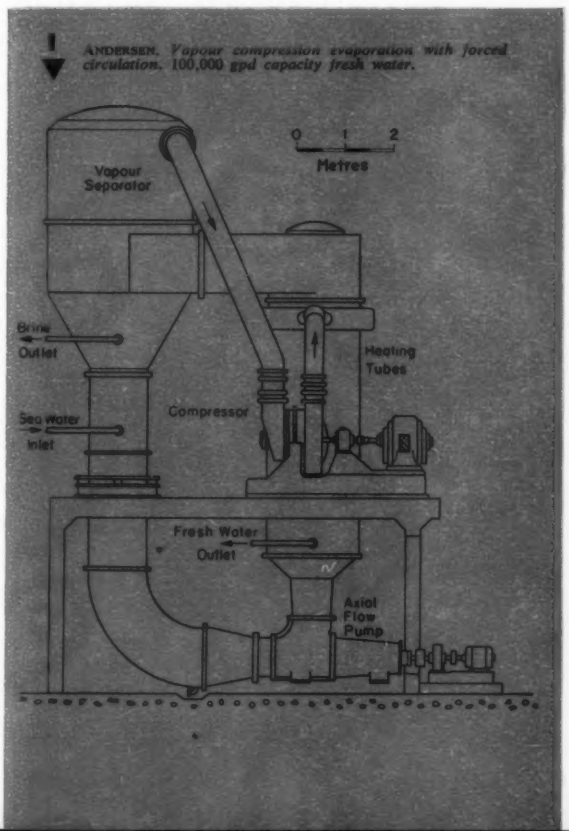
Energy Requirements

Desalination means eliminating salt in sea water, which has approximately 3.5 per cent or 35,000 ppm, or in any case reduction to 500 ppm, a potable range. Minimum thermodynamic energy requirements have been calculated[3, 5] at about 2.6 kWh per 1000 gal. This assumes complete reversibility, a limitless amount of sea water, no pumping costs, no heat losses, etc. Actual processes may require hundreds of times this minimum, although newer processes may possibly reach only 5 times this minimum; i.e., 10 to 15 kWh per 1000 gal.

Reduction of fresh water costs is a tremendous challenge because of the resulting benefits to mankind, the tremendous amount of money which will be spent on equipment for successful processes, and the enormous increment in land value where water is made available.



▲ 2 ANDERSEN. *Vapour compression evaporation with forced circulation. Energy requirements for pump, for compressor, for total as dependent on ratio water evaporated to water circulated.*



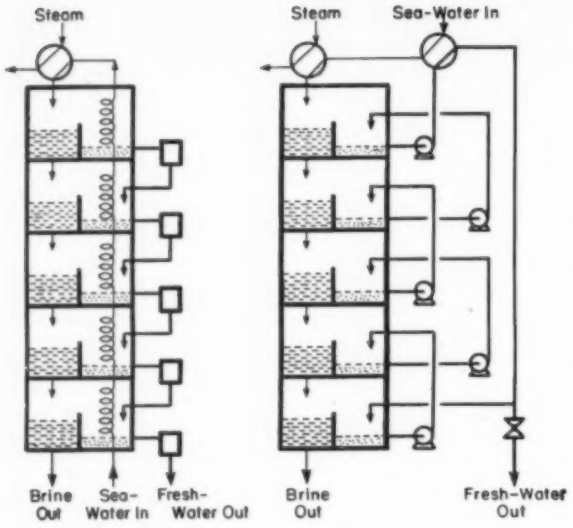
▼ 1 ANDERSEN. *Vapour compression evaporation with forced circulation. 100,000 gpd capacity fresh water.*

Evaporation (Distillation)

For almost 400 years sailors have used simple distilling apparatus to make drinking water; and steamships use multiple-effect evaporators. Solar energy was used almost 100 years ago in Chile, where a glass-roofed unit had over 50,000 sq ft. The last major "break-through" using metallic heat-transfer surfaces was long-tubes with forced liquid circulation in about 1920 in Japan, and a little later in the United States. A current innovation increases heat transfer by wiping off liquid films; this also was described in the last century. However, the sophisticated spinning spheroidal still surface by which HICKMAN evaporates water improves as well as complicates the spinning spheroidal still surface evaporating water in Hero's turbine of ancient day.

Multiple-effect Evaporation

Compound heat use has been studied for 150 years, the apex being the 12-effect OSW demonstration unit. Arrangements of heaters for recuperation, materials of construction, methods of descaling, etc., may yet be improved, but no fundamental improvement is hoped for in the classic design factors. PRESIDENT VANDERSTEEL, of Weir-Chicago Bridge Co., the builder of this dozen-effect unit, said: "Principles involved today were in use 30 years ago. All we



▲ 3 *(a) Multiple flash evaporation using a condensing surface for vapours in each stage to heat the cycling brine to as close as possible a temperature of the steam in that stage. Steam traps allow condensate to flash in going to next lower stage.*
(b) Vapour reheat flash evaporation. Vapours from flashing give heat to fresh water recycled by pumps to successively higher stages, then cooled by incoming sea water. No metallic heat-transfer surface required in heaters or in cooler.

can look for is a series of marginal improvements." These improvements give, in this 1 million gpd unit, a plant cost of about $1250 per 1000 gal per day installed capacity, and fresh water costs estimated at about $1.00 per 1000 gal by the OSW calculation standards. These plant and operating costs require an intimate combination of a desalinating unit with an electric power plant, and could not be achieved by an isolated unit. Costs of plants and product for over 1 million gal per day should not change greatly, since repetitive units would be required. Present understanding limits the number of effects to about 15, so the energy cost cannot decrease importantly.

Vapour Compression Evaporation

Conceived about 125 years ago by PIERRE PELLETAN, a Frenchman, large numbers of portable vapour compression systems were used during the Second World War to supply potable water for combatants on sea islands. In Switzerland and Scandinavia heat is expensive compared to electric energy; and this principle has been used more often than in America in usual chemical evaporator practice. However, the OSW has supported research work, and is now engineering a 250,000 gpd desalination plant.

HICKMAN and others have developed ingenious systems for greatly increasing heat-transfer coefficients through reduction of film thickness by mechanical power. The temperature drop required to transfer heat is thus lowered; and energy requirements are reduced because the pressure range over which vapours are compressed is similarly reduced. A more conventional device to reduce the effective liquid film is to force the liquid at high velocity through heating tubes.

The combination of forced circulation and vapour compression has been optimized by methods and equipment of ROLF ANDERSEN, of Copenhagen. His United States Patent[1] gives economic balances. Fig. 1 is a unit for 100,000 gpd water of a maximum of 2 parts solids per million from sea water. Power is required for (a) compression, by a turbo compressor, of vapours rising from boiling sea water, up to the pressure of the steam chest; also for (b) circulation of sea water through the heating tubes to reduce effectiveness of films and increases heat transfer by a high velocity, expressed as the Ratio of Water Circulated to Water Evaporated.

Thus, the lower curve of Fig. 2 shows that the energy required to force the water through the tubes by the recirculating pump increases as the Ratio of Water Circulated to Water Evaporated increases. Also, as more water is circulated the heat-transfer coefficient increases; the temperature and pressure differentials across the compressor are reduced; and hence the energy required decreases as shown by the middle curve. In the economic range, usually about a quarter as much power is used by the circulating pump as by the compressor. The upper curve is the sum of the energy requirements of pump and compressor. Minimum total energy is in the range where 200 to 1200 times as much water is recirculated as is evaporated. For the problem of Fig. 2 minimum power cost is at a ratio of about 800 times as much water circulated as is evaporated.

ANDERSEN'S system requires 50-70 kWh, per 1000 gal., in installations for concentrating *pulp liquor and other industrial liquors*; for sea water desalination, from 40 to 45 kWh. Water then will cost about 50 cents per 1000 gal in a 1 million gpd plant.

Plant cost is relatively low for smaller installations compared to multiple-effect evaporator or freezing installations, and not greatly different for larger units. Thus, a 10,000 gpd unit might cost $5000 per 1000 gpd, a 100,000 gpd unit might cost $1500 per 1000 gpd and a 10 million gpd unit might cost $1000 per 1000 gpd, depending on materials of construction. ANDERSEN claims means to overcome effect of scaling and of corrosion of steel. The few components permit automated operation.

DODGE and co-workers[3] confirmed ANDERSEN'S results with a small experimental unit. They estimated 46.5 kWh per 1000 gal when about 200 times as much sea water is recycled as is evaporated, with an overall temperature difference of 1.5°C and a compressor efficiency of 80 per cent.

Multiple Flash Evaporation

The adiabatic chilling of hot water in expanding (or "flashing") from a higher saturation pressure causes partial vaporization. The Alberger stepwise flashing used vapours from several steps to heat the feed countercurrently. As many as 15 stages have been used in process liquid evaporators. For sea water conversion, Fluor Corporation, Westinghouse and others use as many as 50 or more stages; with water costs (for a 1 million gpd unit) in the range of $1 per 1000 gal and investment costs of about $1600 per 1000 gpd.[6]

Fig. 3 (a) shows sea water passing in a coil through the right side of a "ladder" of stages of successively higher pressure and temperature, and being heated by vapours generated by flashing of heated brine in passing from higher to lower pressures and temperatures on the left side of the ladder. In a prime heater, steam heats the sea water from the outlet temperature of the top stage to the inlet temperature. To the right are indicated steam traps for allowing the condensate to pass to the next lower stage, meanwhile flashing to give heat through the tubular walls of the condenser section in each stage.

Vapour Reheat Process

The vapour reheat process eliminates metallic heat-transfer surfaces in the heating (condensing) side of the ladder, as well as in the cooling (evaporation) side. This greatly reduces plant costs, scaling and corrosion problems. An outgrowth of a prior patent,[10] it is under development at the Polytechnic Institute of Brooklyn, under contract of

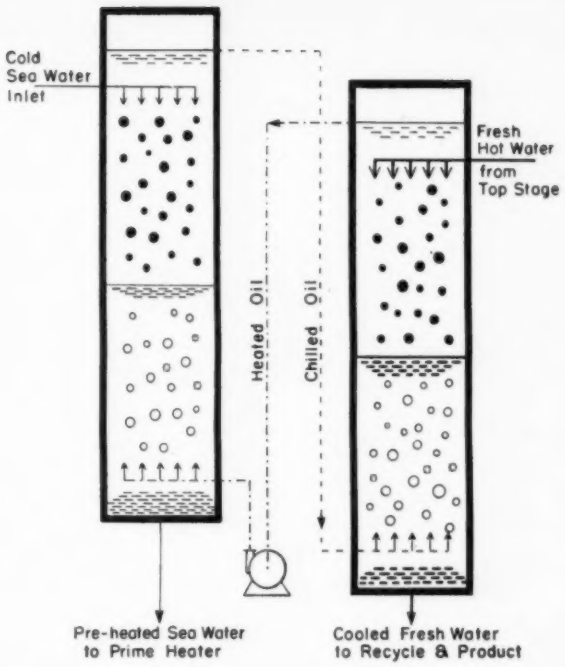
the OSW.[6, 8] Fig. 4 (b) shows the right side of the ladder to have a separate recycle of fresh water by pumps from each stage to the next higher stage. Sprays or films expose an optimum of surface to the direct heating action of vapours coming from the flashers. Condensate from these vapours add in each stage to the amount passing from low temperature to high temperature. In addition to the prime heater, there is a heat exchanger to heat the entering sea water with the heat absorbed in the fresh water (condensate) side.

In any stage the two liquid streams are separated so as to permit free passage of water vapour from the hot side to the cold side. Large numbers of stages may be superimposed within a single shell, as plates in a distillation column. Within each stage the brine and cold water approach equilibrium of vapour pressure. As also in a distillation column, the two fluid streams are in parallel flow relationship at an individual stage, and a larger number of stages reduces heat requirements and 20 to 50 or more stages are desirable. When there are no non-condensable gases, brine and water leave any stage at almost the same vapour pressure (or temperature if boiling point elevation is not considered). The final equilibrium temperature is a function of the relative flow rates of brine and water. Calculating the performance of a single stage involves only a heat and material balance with exit streams at equilibrium. A cascade presents a greater problem, however, since at each stage the temperatures, flows, concentrations, etc., must be determined sequentially. This involves a multiple trial and error computation. Values of temperatures, flow rates, amounts of evaporation and brine compositions must be assumed at first, then modified during the calculation to reach a satisfactorily converged solution. The programme has been developed for such a solution on an IBM 650 computer; and characteristics have been obtained for a large number of possible combinations.

Direct Contact Vapour-liquid Heat Exchanger

The vapour reheat process eliminates the large condensing-heating surface of the coils of Fig. 3. To eliminate all metallic heat-transfer surfaces, the cold sea water may be preheated in a direct contact liquid-liquid heat exchanger, similar to that used since 1954 by UMANO[9] in his freezing process described below; it has been used by WOODWARD[13] and others.[11] Fig. 4 shows it to consist of substantially liquid-liquid extractors of the "open tube" or "droplet" type. Herein the lower continuous phase in each is aqueous, and the upper phase is a specially selected petroleum oil carrying the heat from the fresh hot water to the cold sea water. The oil carries practically no salt from the sea water (left) unit to the fresh water (right) unit. Special distributing plates with holes or nozzles eject as drops the aqueous streams near the top, and the oil streams near the bottom. The aqueous drops settle downwardly to the interface, where they coalesce; and the oil streams emerge as drops which settle upwardly through the aqueous phase and thence coalesce at the interface. Very large heat transfer surface areas are thus obtained on the surfaces of the drops; and the vessel cost is low by comparison to a tubular heat exchanger of the same capacity. A design coefficient may be 2500 Btu/hr/cu ft/°F overall temperature drop.[13] Thus 1 cu ft equals about 8 sq ft of a shell and tube heat exchanger. Similarly, the prime heater, utilizing steam to heat the pre-heated sea water to the temperature of the top flash, may transfer heat from steam to oil to sea water by direct contact.

Besides the large saving in cost by eliminating solid heat-transfer surface, scaling is also eliminated. Scale-forming solids may be precipitated and eliminated by a settling tank. This elimination of scaling allows a flasher system to operate at a high temperature with a large number of flashers and with comparatively high efficiency.



▲ 4 *Liquid-liquid-liquid heat exchanger for preheating sea water with hot fresh water by an intermediate oil used as a heat transfer medium to sea water.*

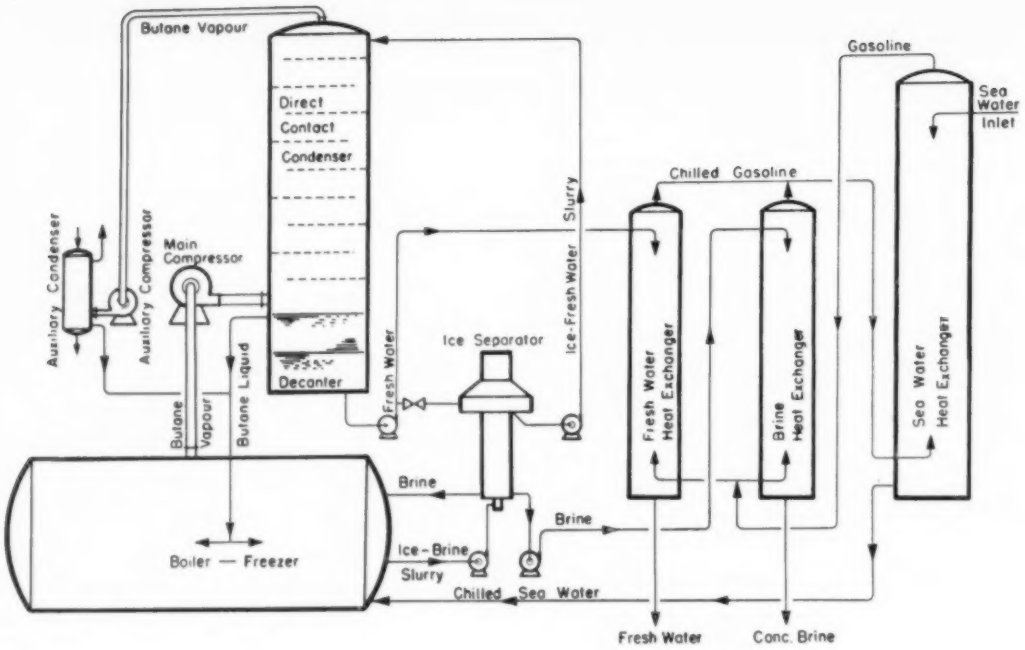
General Comparison of Evaporation Processes

Of the three basic evaporating processes, the multiple-effect system has been most studied. Elevation of boiling point limits the number of stages to a maximum of probably 15 for sea water use. Elevation of boiling point also increases power cost of compressor in the vapour compression system. In the vapour reheat process and other multiple-flash evaporation systems, regardless of the number of stages, the boiling point elevation is only effective once. The vapour reheat process apparently has the additional advantage of low equipment cost and no scale troubles, since it eliminates metallic heat-transfer surfaces. This allows a higher operating temperature, and reduces the loss in effective temperature drop. Furthermore, in the vapour reheat process the condensate in each stage passes to the next higher stage along with the recycle fresh water rather than to the next lower stage as in the multiflash system with heat-transfer surfaces. For these three reasons, a lower heat cost will be possible, about 500 lb of steam per 1000 gal of water, depending on terminal conditions.

Thus, for the vapour reheat process as compared with other evaporation systems, in large installations capital cost will be lower; practical operation appears to be more simple and economic; and heat costs should be lower. For installations of smaller capacity, the plant cost will be higher per unit of production because of the relatively greater importance of the cost of the recycle pumps; and ANDERSEN'S forced circulation, vapour compression may be cheapest.

Freezing Processes—General

Freezing has long been considered for separating fresh water from sea water. It has a temperature fixed by brine concentration—while evaporation can operate over a wide temperature range. Fundamentally, freezing has: (a) less heat losses (gains) because of working at temperatures closer to the ambient; (b) no trouble with scale forming



▲ 5 *Umano freezing process—no metallic heat transfer surfaces. Fresh-water ice formed by evaporating butane; centrifugal ice separator removes ice from brine, makes fresh water slurry with ice which melts on passing to direct contact condenser as butane condenses for recycle.*

impurities; and (c) much less corrosion of steel at the freezing point than at the boiling point of water; and at the lower temperatures other materials may be used, e.g., concrete and plastics. In freezing there is a relatively high cost of removing heat as compared to adding heat; but it may be considered if electrical or mechanical energy is cheap.

The Carrier desalination process uses water vapour as the refrigerant in an adsorption refrigeration system. ZARCHIN in Israel may be using water vapour also, although his patented method for the separation of small crystals specifies other refrigerants. The low vapour pressure at the freezing point of concentrated brine gives a tremendous volume of vapours per pound water evaporated. A refrigerant boiling at or near this freezing point would have only a fraction of a per cent of the volume of vapours to be handled, and no vacuum system to maintain.

OTHMER in 1930[7] discussed a process suggested some years before wherein boiling butane at about 0°C froze ice crystals by direct contact, and the butane vapours were later condensed in melting other ice. JENSEN in 1946[4] desalinated sea water, using butane as a refrigerant with an ingenious system of separation of ice from a slurry with brine by adding fresh water near the middle of the floating ice bed. Ice crystals were removed and melted by condensing butane vapours. A modification of this process has been described by WEIGANDT,[12] supported by the OSW. ZARCHIN in Israel, Carrier, Blaw-Knox, Scientific Design with STRUTHERS WELLS, and others, have developed ingenious related systems, none of which has operated as yet in practice.

Umano Freezing Process

To this date, the UMANO[9] plant is the only sizeable one built, and *operated* for months or years for freezing and separation of ice, equivalent to 52,000 gal or 200 metric tons of fresh water per day, by direct growth of crystals in contact with a boiling refrigerant, preferably isobutane. This Japanese development is now being engineered by Clark Brothers Co., one of the Dresser Industries of New York.

General Costs

Plant cost and production costs are lower than for any other freezing, evaporation or other process which has operated anywhere on a plant scale of this size over a period of years. A plant of 50,000 gpd capacity was built for about $100,000; a plant for 1 million gpd (1100 acre ft per year) has been estimated at less than $1 million. The low capital cost results from: (a) basic simplicity; (b) operation near atmospheric pressure; (c) minimal corrosion due to low temperatures—thus concrete, steel and cast iron may be used; (d) absence of metallic heat transfer surfaces; (e) absence of scaling on metallic heat transfer surfaces—since there are none; and (f) relatively modest sizes of the equipment. Thus a plant for 10 million gpd may be a *single* unit with several ice separators. The largest turbo-compressor is a single unit of 300,000 cfm, as against 120 units of this size calculated by Carrier Corporation for a direct water-vapour-refrigeration system for the same capacity.

The total energy requirement is 7.13 kWh per metric ton of desalted water, or 27.2 kWh per 1000 gal. This is based on pilot plant operation; lower values may result in a large installation. The actual production cost, including capital charges in a plant of 1 million gpd, have been calculated to be in the range of $0.35 to $0.45 per 1000 gal of fresh water produced.

Umano Process Description

In Fig. 5 sea water at 15°C is deaerated, then is prechilled while heating the products: concentrated brine and fresh water. It is mixed in the freezer-boiler with liquid butane which vaporizes, as ice crystals freeze to give brine twice as concentrated. Ice crystals leave in a slurry with brine.

Relatively large ice crystals result in the ice separator,

1 mm or larger, allowing easy drainage and washing with a small amount of sea water and an even smaller amount of fresh water. Fresh water at 0°C carries crystals away. Brine returns to the freezer or goes through a heat exchanger to discharge.

A slurry of ice crystals in a recycle stream of fresh water passes to the main condenser, to be contacted directly with compressed butane vapours. As in the freezer-boiler, heat transfer is almost isothermal; here condensation takes place at 0°C. Liquid butane condensate is returned to the freezer; part of the fresh water recycles to the ice separator and mechanically transfers the crystals to the main condenser. The balance of the fresh water is heat interchanged to chill the entering sea water, then leaves as product.

Butane vapours leaving the freezer-boiler are compressed in the main compressor in a ratio of 1.27 to a higher pressure and temperature which allows heat transfer and condensation to melt the ice crystals.

Due to thermodynamic inefficiencies, somewhat more butane vaporizes in the freezer-boiler than can be condensed by the melting ice. This amount must be compressed in an auxiliary compressor by a ratio of 1.94. Direct contact gives condensation in the auxiliary condenser with one of the chilled streams; i.e., the desalted fresh water or brine leaving the system. Non-condensable gases are purged by a vacuum pump; this is also connected to a deaerator, not shown, for the entering sea water.

Heat exchangers are countercurrent, liquid-liquid, direct contact devices of the same type noted under the vapour reheat process, independently developed by DR. UMANO. The two smaller units have streams of cold liquid brine and product water respectively, bubbling up in countercurrent with warmer gasoline, which is chilled. The chilled gasoline from both is combined and, in turn, is warmed by countercurrently contacting raw sea water, which is thereby prechilled.

Heat Transfer and Compression Ratios

There are no metallic heat-transfer surfaces; and the very low temperature drop available is used most advantageously through direct contact of the hot and cold phases.

With a thermodynamic efficiency of 100 per cent there would be a zero temperature of approach in the freezer-boiler and in the main condenser. The only heat requirement would then be the opposite of the heat of concentrating the brine, about 2.8 kWh per 1000 gal. There are much larger heat losses and thermodynamic inefficiencies; and the amount of butane gas which passes to the main condenser and cannot be condensed therein represents roughly the thermodynamic inefficiency.

Since the vapours are near atmospheric pressure, and the compression ratios are small, these compressors operate efficiently. At the freezing point of the brine, water has about 1/200th atm. pressure; and a comparatively very large volume of vapours would be required if water vapour were to be handled. Also, a very high compression ratio is required to increase the pressure and temperature of water vapour so it will condense to melt the ice.

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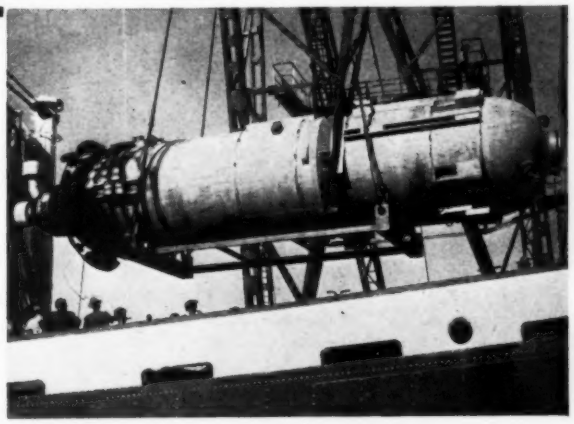
Swedish Plant For Britain

A MAIN process vessel for a plant under construction for The Distillers Co. Ltd. has just been shipped to the U.K. from Sweden by the Uddeholm Co.

The Degerfors works of the Uddeholm Co. is among others well known as manufacturers of the pressure vessel for the Ågesta station—the first commercial nuclear energy plant in Sweden. The works also manufacture other heavy-walled pressure vessels for chemical, pulp and oil industries, steam plants, etc.

A few days ago a heavy pressure vessel in solid stainless steel was completed at Degerfors. This pressure vessel is designed for a chemical plant under construction at Hull for The Distillers Co. Ltd. It is constructed in heavy-gauge stainless-steel plate and will be a major unit in a process developed in the company's own laboratories.

The well-known engineers, The Lummus Co. Ltd., were entrusted with the design and construction of the new plant.



The heavy pontoon crane lifting the big pressure vessel on board the s.s. Rollo *at the port of Gothenburg for shipment to Hull.*

Uddeholm has previously supplied Lummus with big welded pressure vessels for the Koppartrans refinery at Gothenburg in Sweden.

Recently the s.s. *Rollo*, of the Swedish-Wilson Line, left Gothenburg bound for England with the heavy pressure vessel in its hold. The usual cranes could not be used for the lifting of a vessel weighing 60 tons, so a heavy-lift pontoon crane was used for the giant lift.

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THE PERFORMANCE OF CONDENSERS FOR CORROSIVE VAPOURS

The condensing capacities, under works conditions, of examples of each of several common simple types of condenser used for condensing corrosive fluids in the fine chemical industry are recorded. The operational conditions were varied and some quantitative information, concerning the effects on capacity of condensate temperature, presence of incondensables and types of fluids condensed, is recorded. An attempt is made to present relevant data in a form which enables a ready comparison to be made between the performances of various types of standard condenser

by F. R. WHITT

IN the fine chemical field in particular, a choice often has to be made from a number of types of standard, commercially obtainable, corrosion-resistant equipment. Frequently the product must not be contaminated by dissolved materials originating from the walls of the processing equipment. This means that, in the case of distillation plant, at least the condenser and distillate receiving equipment must be fabricated in a material as inert as is practical. Glass or glass-enamel coatings are almost insoluble in a great variety of corrosive fluids or vapours, and can be used for, or incorporated in, the construction of process equipment intended for a wide range of uses. Other corrosion-resistant materials available and suitable for the construction of chemical plant are processed carbon (e.g., Delanium, Carbinert, etc.), Hastelloy, tantalum and silver. All have various advantages and disadvantages, compared with the glass or glass-enamel-coated materials, for particular purposes. Silver, for instance, is particularly satisfactory for the construction of equipment which must be resistant to the corrosive action of free hydrogen fluoride together with hydrogen chloride in mixtures of organic phosphorus halides.

The peculiar mechanical properties of glass and glass-enamel-coated metal place certain restrictions upon the design of any process equipment incorporating these materials. Manufacturing and operational experience have produced certain standard patterns and the equipment itself is supplied by specialist manufacturers only.

The main purpose of this paper is to present some operational data obtained from the use of the standard equipment mentioned above, in particular condensers, and to compare the performances of these standard non-metallic type condensers with those of some silver condensers. It is probable that if these silver condensers had been made from other corrosion-resistant metals the heat-transfer performances would have been very similar. The comparisons could therefore be assumed to be valid for metals other than silver.

The durability of some glass-enamel-lined equipment has been described in the literature[1] and it can be safely assumed that accidental breakage will be the sole factor of importance in deciding the working life of glass equipment. A point in favour of using corrosion-resistant but expensive material, like silver, can be said to be that equipment manufactured from it has a high scrap value,[2] which tends to balance out the high first cost. The technique used in manufacturing silver equipment has been described by PIRIE.[3]

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Heat-transfer Calculations for Condensers

The prediction of the condensing capacity of a condenser, using a combination of heat-transfer coefficients which have been determined under controlled conditions in the laboratory, is not a reliable procedure.[4] The performance of large vacuum steam condensers for use in electric power stations has been the subject of much experimental work, and the general conclusion is that practical tests alone provide a reliable guide to the overall heat-transfer coefficient of a condenser. One of the heat-transfer problems encountered when trying to estimate a condenser performance is the quantitative effect of the change of vapour rate over the condensing surfaces. Estimations of the effects of the presence of incondensable gases in the vapours are also difficult to make. On the cooling fluid side of the heat-transfer wall the effects on heat transfer of water motion in tube head boxes and fouling films are of major importance and must be taken into account.

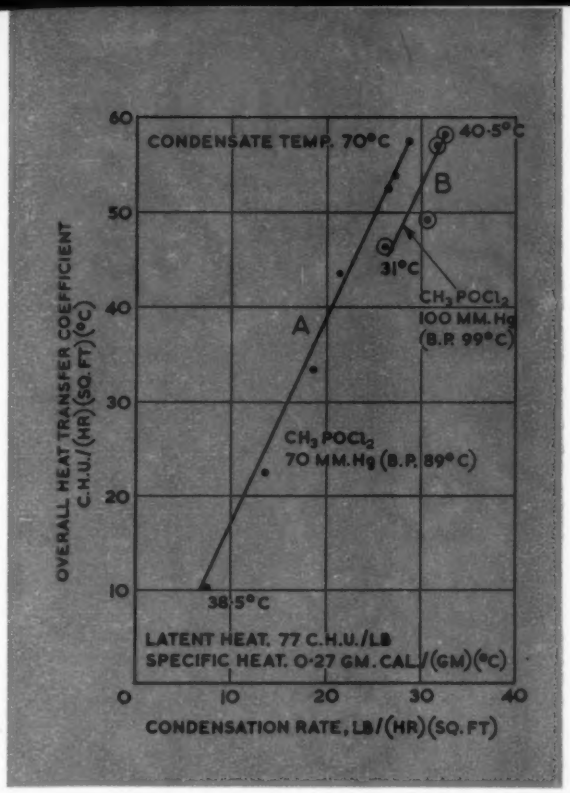
The above problems are also encountered with the smaller types of condenser such as those reported upon in this paper. In addition, the vapours handled by these smaller condensers may contain high proportions of various incondensable gases generated, for example, as by-products from the processing of organic chemicals. There is clearly a need[6] for more experimental data on the condensing film coefficients of organic vapours and also the effect upon coefficients of the presence of incondensables other than air. In the case of the condensers reported upon in this paper the vapours processed were polluted, in general, with small quantities of hydrogen fluoride or hydrogen chloride. Methyl chloride and chlorine were other polluting materials which were incondensable under the conditions of operation.

With glass-enamel-lined equipment the composition and thickness of the lining can vary within each item, and trials on the complete units[1] are the most reliable guides to heat-transfer capacities.

Experimental

(a) *General*

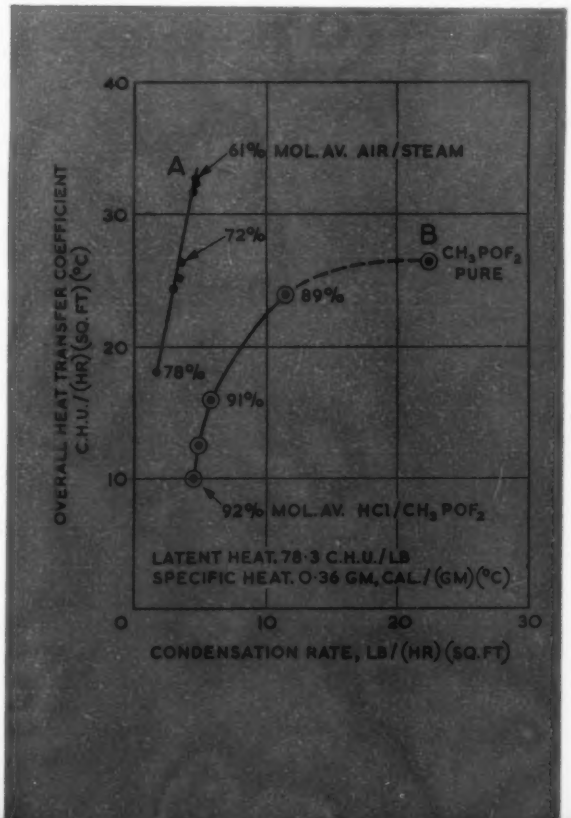
Data obtained from the use of semi-technical-size condensers are presented as Table I. The overall heat-transfer coefficients recorded were, in general, calculated from the heat received by the coolants. It was found that only in the

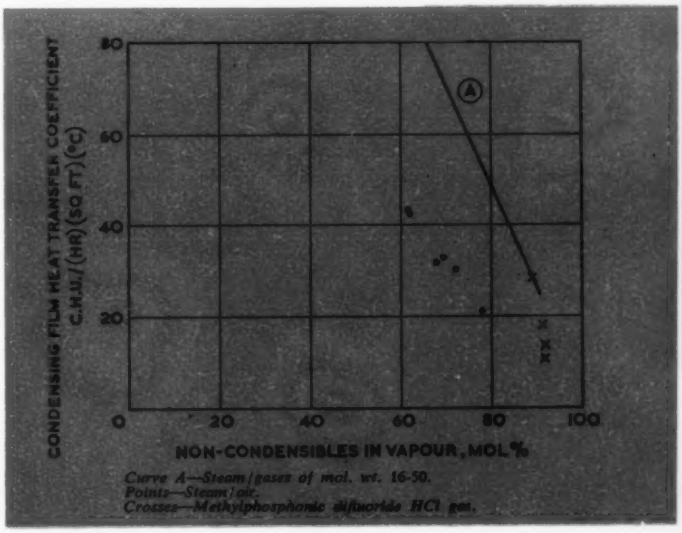


▲ 1 *Effect of condensate temperature.*

Condensing film heat-transfer coefficients for vapours containing non-condensables. 3▶

2 ▼ *Effect of incondensables.*





case of condensers having several square feet condensing surface was it possible to calculate a reasonably satisfactory heat balance. Small condensers, of about 1 sq ft cooling surface, lose a disproportionate amount of heat to the surrounding air. It will be noted also that the condensing vapour film coefficients, and wall resistance in some cases, are the predominant factors deciding the condenser performances. The effect of the resistances of the water side or dirt films, when organic vapours are being condensed, is not very great.

All condensers reported upon in this paper were unlagged and in most cases extra condensation resulted, which was calculated to be equivalent to about one-tenth of that caused by the water-cooled surfaces. In the case of small laboratory-type glass condensers, however, the extra condensation due to cooling by the surrounding air was much greater, and amounted to about one-half of that produced by the water-cooled surfaces alone.

The overall heat-transfer coefficients were calculated from the gross heat transferred, as measured by that received by the cooling fluid, divided by the difference in temperature of the condensing vapour and the average of that of the cooling fluid. No attempt is made to split up the condensing and cooling of condensate coefficients. The condenser performance figure emphasized in this paper, the rate of condensation per unit area, was, in general, an unambiguous experimentally measured quantity.

(b) *Special Cases*

Figs. 1 and 2 present data, from experimental runs on particular condensers, which demonstrate quantitatively the effect upon the condensing capacity of either the temperature of the condensate or the presence of incondensables in the vapours.

Data given in Fig. 1 were obtained from the operation of a 5 sq ft cooling surface silver tube condenser (19 tubes of 17 mm bore). The vapour was inside the tubes which were positioned vertically. Two pressures of operation were used which resulted in the average boiling points of the condensing methylphosphonic dichloride being 89°C and 99°C. As the setting point of the material is about 30°C, the lowest operating condensate temperature was 38.5°C.

Inspection of curve A on Fig. 1 shows that the condensation rate with a condensate temperature of 38.5°C was only

TABLE I.—Performance of Glass-enamel-lined, Glass and Metal Condensers
(Water or calcium chloride brine used as cooling liquids in 0·25–0·71 in. bore tubes)
(Cooling liquid film heat-transfer coefficients, 100–200 CHU/hr. sq ft °C)

Condensing Material	Constructional Material	Type	Condensing Surface, sq ft	Condensate		Apparent Overall H.T.C., CHU/hr sq ft °C	Maximum Vapur Rate, lb/hr sq ft free cross-section	Heat Flux, CHU/hr sq ft
				Rate, lb/hr sq ft	Temp, °C (1)			
Benzene	Cast iron, glass-enamel lined	Cooled thimble in cylinder (double surface)	9·0	4·5	20·0	8·0	670	560
Dimethylhydrogen phosphite				6·6	22·0	15·0	1000	750
Ethyl alcohol				3·3	26·0	12·7	500	760
Ethylphosphonic dichloride ($C_2H_5POCl_2$)				5·9	7·2	6·2	885	620
Methylene chloride				4·9	8·4	8·4	740	470
" "				2·8	5·0	5·0	425	280
Aqueous formic acid			16·0	4·9	25·0	33·0		2300
Thioacetic acid	Mild steel, glass-enamel lined		14·0	6·6	25·0	10·1	816	630
Benzene			14·0	5·1	25·0	10·8	600	640
Methylphosphonic dichloride	Glass	Cooled tube bundle in vapour space	3·5	7·7	38·0			
Phosphorus oxychloride			3·5	15·1	25·0			
Methylene chloride			5·0	8·0	25·0	27·8	800	640
Sulphur dichloride (10 per cent Cl_2)			12·0	11·4	56·0	33·0	3400	800
" "			9·0	5·5	35·0	11·5	1140	333
" " (Ref. [7])			5·0	21·0	45·0	43·0	2100	1200
" "		Double-surface laboratory type	1·8	4·4	37·0	15·0	—	374
" "			0·4	17·0	55·0	18·0	—	460
Methylene chloride	Silver	Cooled straight tubes in vapour space	130·0	4·2	17·2	28·5	340	356
" "			130·0	12·5	14·0	57·0	1020	1020
Methylphosphonic difluoride			15·0	22·5	56·0	26·8	370	1600
Methylphosphonic difluoride with HCl gas entrant 85 per cent mol HCl gas (av. 92 per cent)			15·0	4·15	32·0	10·0	218	422
Methylphosphonic difluoride 78 per cent mol (av. 89 per cent)			15·0	11·2*	21	24·0	356	1010
Methylchloroacetate		Cooled tube bundle in vapour space	12·5	22·5	69·0	25·6	1790	1000
"			7·2	12·2	74·0	17·7	1120	972
"			2·46	20·5	69·0	29·0	760	1630
Methylphosphonic dichloride		Vapour in tubes	5·0	21·2*	38·5	43·5	2950	16·50
Methylphosphoric dichloride (CH_3POCl_2)			5·0	36·0*	72·0	62·5	5000	2820
Steam with air (78 per cent mol av.)	Mild steel	Cooled thimble in. dia. in shell 3½ shell 6 in. dia.	4·2	1·9*	60·0	18·2	174	1025
" " (61 per cent mol av.)			4·2	4·79*	60·0	32·5	218	2500

* See also Figs. 1 and 2.

one-third of that achieved with a condensate temperature of 70°C. From these figures it can be estimated that the condensation rate at reflux temperature would be about 40 lb/hr sq ft, and also that when a condensate temperature of 38.5°C is achieved about 4 sq ft of the 5 sq ft condenser surface was used for condensate cooling purposes.

The water flows used were 145-177 lb/hr in the case of the condenser experiments giving rise to curve A and 145-200 lb/hr in the case of curve B. Estimations suggested that the water side film coefficients should be about 200 CHU/(hr) sq ft °C; i.e., would be very high compared with the other film coefficients.

The data given in Fig. 2 as curve B were obtained during the operation of a 15 sq ft cooling surface condenser (19 horizontal tubes of 19 mm O.D.) in which the vapour condensed outside the water-cooled tubes. The entrant vapours of methylphosphonic difluoride and hydrogen chloride and the range of average composition (assuming the exit vapour to be 100 per cent mol hydrogen chloride) was 89-92 per cent mol. As will be seen from data given in Table I, some condensate sub-cooling, below the temperature of the entrant vapours, took place, but these variations were such

TABLE II.—Comparison of Performances of Condensers
(See Figs. 1 and 2 for details of those marked *)
(Results for (Water*) obtained from Manufacturers' Catalogues)

Condenser Details					Condenser Performance (Average)		
			Maximum Size (sq ft)		lb Condensate per hr per sq ft Cooling Surface		
Material of Construction and Type	No. Tested	Fluids Tested	Tested	Standard Manufacture	Cold Condensate (1)	Hot Condensate (2)	Gas Cooling and Warm Condensate (3)
Glass-enamel-lined cast-iron or mild steel. Double surface	3	7 (organic)	16	62	4·9 (18°C)	—	—
		(Water*)	62	62		8	
Glass—Bundle of straight tubes, or coil, in vapour space	6	4 (non-aqueous)	12	60	8·0 (25°C)	11·9 (43°C)	—
	4	(Water*)	14·5	60	3·02 (25°C)	10·8 (44°C)	
Silver—Bundle of straight tubes, or coil, in vapour space	6	5 (organic)	130	100	15·1*	22·7*	4·15*
Mild steel. Cooled thimble in vapour space.	1	1 (Water)	4·2	—	—	—	1·9*

Temperatures, °C			Rate Ratio Cooling Liquid Condensate	Operation Pressure, mm Hg
Vapour Inlet	Inlet Coolant (2)	Approach of Condensate Temperature to Inlet Cooling Fluid (1)—(2)		
80	10·0	10·0	126	Atmos.
60	10·0	12·0	84	12
78	10·0	16·0	169	Atmos.
85	—16·7	23·9	—	35
40	—16·7	25·1	—	Atmos.
40	—16·7	22·7	—	600
101	20·0	5·0	18·3	Atmos.
75	8·0	17·0	18·1	,,
77	8·0	17·0	14·0	,,
99		64·0		100
48		33·0		Atmos.
40	13·0	12·0	10·0	,,
57	13·0	43·0	2·18	,,
57	—13·0	48·0	20·2	,,
56	13·0	32·0	11·5	,,
37	—8·0	45·0	30·0	,,
55	23·0	32·0	1·3	,,
40	16·67	0·53	34·5	,,
40	11·46	3·14	31·0	,,
80	9·0	47·0	23·6	400
65	6·9	25·9	88·8	600
65	6·2	14·8	47·6	600
69	12·0	57·0	1·77	50
74	12·0	62·0	88·0	60
69	12·0	57·0	88·0	49
86·5	20	18·5	1·36	70
91·5	20	52·0	1·52	70
63·3	4·0	51·9	521·0	,,
98·8	4·8	51·2	285·0	Atmos.

that it could be assumed that the effect of the incondensable hydrogen chloride was the major factor governing differences in condensing capacity. In Fig. 2 and Table I data are given showing the capacity of the same condenser when methylphosphonic difluoride alone was condensing. Inspection of curve B shows that when 92 per cent mol hydrogen chloride was in the condensing mixture the capacity of the condenser was reduced to about one-fifth of that when pure methylphosphonic difluoride was condensing.

For purposes of comparison, data concerning the performance of a simple, water-cooled thimble in a vapour-type, mild-steel condenser handling steam/air mixtures are given in Fig. 2. From curve A it will be seen that a change in average air content of 61 per cent mol to 78 per cent mol reduced the steam condensing capacity by a ratio of 1.9/4.79

Condenser Performance (Average)		Weight (empty) lb	
Range of Overall Heat-transfer Coefficients, CHU/hr sq ft °C		Per sq ft Surface	Per lb Condensate per hr (1)
(1) and (2)	(3)		
5 to 33		34	7·70
		34	4·2
11·5 to 43		1·55	0·19
		1·55	0·45
17·7 to 52·5	10 to 24	11·0	0·6
—	18·2 to 32·5	—	—

TABLE III.—Physical Properties of the Condensed (Non-aqueous) liquids

	Range
Latent heat	70—208 CHU/lb at atm. b.p.
Specific heat	0·25—0·6 gr. cal per gr. per °C.
Density	0·8—1·6 g per cc.
Viscosity	0·45—1·65 cp
Boiling point (test conditions)	40—99°C
Thermal conductivity	0·084—0·1 CHU/hr sq ft °C per ft

(1 CHU = heat required to raise 1 lb water 1°C.)

or 1/2.4. If steam, free from air, were condensing, estimations suggest that the condensing rate would have been about 15 lb/hr sq ft: Data given by KERN,[5] p. 367, concerning the heat-transfer coefficients of steam/gas (incondensable) mixtures have been plotted on Fig. 3 along with film coefficients deduced from experimental data, examples of which are given in Table II. It appears that although the values for the coefficients quoted by KERN[5] are higher for the richer mixture range of steam/air, all the data appear to converge to a common value at about 90 mol per cent incondensables. An equation is given in Ref. [8] for calculating heat-transfer coefficients for mixtures of steam in a steam/air mixture of from 99 to 67 per cent. It was found that this equation predicted values roughly midway between those of curve A and the point steam/air values of Table I, as plotted on Fig. 3.

Experimental data have been published[5, 9, 10] on the film coefficients of steam/air mixtures containing very small to moderate quantities of air, but the literature is sparse on data for high percentages of air in steam/air mixtures.

Conclusions

An attempt is made in Table II to summarize data obtained from plant operation in such a form that some general conclusions can be drawn. These conclusions may be of use in circumstances other than those which gave rise to the data supporting them.

The condensing capacities, for non-aqueous vapours, of the three types of condenser, classified according to material of construction, appear to be in the approximate quantitative order of 1/1.6/3.

The weight of condensing equipment needed for a given performance is a minimum for glass construction.

The cost of silver and glass equipment is discussed by RUMFORD[3] (p. 229 and p. 326 of Ref. [3]) and information is, of course, also available from manufacturers. It appears that, from first cost alone, glass equipment is cheaper.

Figs. 2 and 3 show, for various types of condenser, the large reduction in condensing capacity which is brought about when the condensing vapours contain a high proportion of incondensables. Fig. 1 shows the reduction in capacity which results when a condenser is used to produce a cold compared with a hot condensate. These data should, at least, provide a practical preliminary guide to designers faced with problems of a similar nature.

ACKNOWLEDGMENTS

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66.087: 621.359.4

DESIGN AND DEVELOPMENT OF A MINIATURE ELECTROSTATIC PRECIPITATOR

The design of a miniature electrostatic precipitator is discussed and the use of the basic equation (residence time and efficiency) is indicated.
The question of minimum applied high-tension potential is solved by actual observation rather than by an academic approach.
The final design of the precipitator as given emphasizes the simplicity of construction and ease of maintenance

by R. H. UNSWORTH

THE miniature precipitator described below was originally devised to free a continuous sample of crude coal gas from inherent tar fog. The sample was required in connection with the automatic mixing of coal gas and producer gas to maintain a constant calorific value of the mixture. The situation was such that the sample had to be extracted at a point very near to the foul gas main.

After considering the various methods of tar fog removal, it was decided that the most efficient and reliable one would be by electrostatic precipitation.

It is known that when a wire of comparatively small diameter is placed concentrically in a metal tube and the wire is held at a high negative potential with respect to the tube, then a measurable current will flow from the wire to the tube. This will cause any particulate matter in suspension in the gas within the tube to migrate to the tube wall, where it can be collected and removed.

It was necessary to consider the problem from the following aspect.

(1) Residence time of gas within the precipitator.
(2) Minimum high tension potential to give an effective removal of tar fog.
(3) Ease of maintenance and cleaning.

Residence Time

Since the sample was required in connection with a three-term automatic controller, residence time had to be kept down to a minimum, as the efficiency of the controller would suffer if the time lags were unduly large.

The expression relating efficiency and residence time is:

$$\log (1 - E) = t \log K$$

where E = the efficiency (expressed as tar fog concentration at inlet minus tar fog concentration at outlet divided by the tar fog concentration at inlet);

t = residence time, sec;

K = a factor depending on the precipitator itself, found in our case to be 0.4.

From the above expression the efficiencies for various residence times are calculated.

Residence time (sec)	Efficiencies
1	0.6
2	0.8399
3	0.9359
4	0.9744
5	0.9898
6	0.9921
7	0.9983

Form of Precipitator

As suggested in the introduction, the precipitator could be conceived as being a steel tube having an electrode (a small diameter wire) placed centrally and insulated from the tube. The gas would enter at the bottom and leave free of the tar fog at the top.

The sampling rate of the gas was fixed at about 16 cu ft per hour. The residence time for various sizes of tubes is given:

Tube diameter (in.)	Free volume (cu ft per ft of tube)	Residence time in seconds = free volume ÷ 0·0044
¾	0·00306	0·695
1	0·00545	1·227
1¼	0·00852	1·936
1½	0·01227	2·789

The 1½-in.-bore tube looked the most promising, and if this was made 18 in. long residence time would be 2.789 × 1.5 sec = 4.18 sec.

This residence time corresponds to an efficiency of about 0.975 and this was considered satisfactory.

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Minimum High-tension Potential

This aspect was important because of the following:

(a) The lower the high-tension potential, then the lower would be the cost of the high-tension rectifier producing the potential.

(b) The simpler would be the construction of the insulator supporting the high-tension electrode.

(c) The more stable would be the discharge.

Undoubtedly, the minimum voltage could be approached from a theoretical standpoint. This would involve the use of certain factors and constants which were not known and which could not be readily obtained. It was decided, therefore, to approach the problem from a practical viewpoint. Accordingly, a "mock-up" of the precipitator was made. This consisted essentially of a 1½-in.-bore tube with an ⅛-in.-diameter electrode placed centrally in the tube. The electrode was insulated from the steel tube by a bakelite bung. The tube was arranged with side branches—one at the bottom, the other at the top—so that gas could be passed through.

A preliminary test was done on air in the tube. It was found that the discharge was quite stable up to an applied potential of about 12 kV; beyond this the voltage collapsed, accompanied with arcing.

Crude coal gas was next passed through the apparatus and the critical voltage fell to about 10 kV. Below this figure the discharge was quite stable and the applied voltage was maintained.

At about a potential of 7 kV it was found that the precipitation of the tar fog was more or less complete, the corresponding current discharge being about 0.6 milliamp.

Accordingly, it was decided to employ an applied voltage of 0 to 10 kV. A high-tension rectifier was built, this being a simple affair embodying primary and secondary windings with two half-wave valve rectifiers and smoothing condensers. It was thus possible to obtain a direct current at a maximum voltage of 10 kV.

Ease of Maintenance

It would be necessary to be able to clean such parts as the electrode and renew it at intervals. This was borne in mind when designing the final precipitator, arrangements being made so that the electrode could be removed easily, cleaned and put back with the minimum of delay.

The precipitator as designed and made is shown in the diagram. This could be made quite easily in any well-equipped plant workshop.

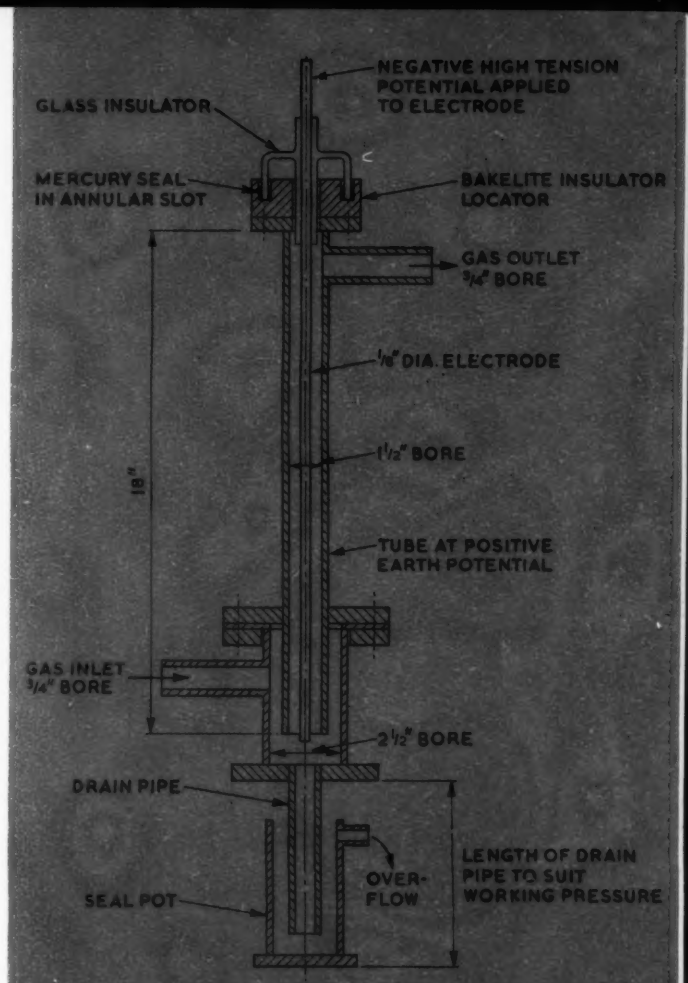

Fig. 1. Miniature electrostatic precipitator.

Whilst this precipitator was conceived and designed especially for use on crude coal gas, it could be used on any containing dispersoids which require removal.

Refinery Gases Into Town's Gas

AUSTRALIA'S first catalytic reforming plant for the conversion of refinery petroleum gases into standard town's gas came on stream on October 13 at the works of the Geelong Gas Co. in Victoria.

The opening ceremony was performed by the Honourable, the Premier of Victoria, MR. H. E. BOLTE.

The installation was designed and constructed by the Sydney office of a British company, Humphreys & Glasgow Ltd., international contracting engineers, who have built similar plants throughout the world.

The Geelong Gas Co. was founded over a century ago. Last year, it produced some 600,000,000 cu ft of gas. Thus the new Onia Gegi plant will supply a big proportion of the city's gas supply.

It will consist of two catalytic reforming units, each with a capacity of 1,500,000 cu ft per day of town's gas. The feed stock will normally be tail gases piped five miles direct from the Shell refinery at Corio.

To cater for refinery maintenance periods the reforming plant will use as an alternative feed stock liquefied petroleum gases (L.P.G.) which will be held in store at a near-by tank farm.

During the reforming process, refinery gases mixed with steam pass through a special nickel-base catalyst at a temperature of approximately 850°C, where the hydrocarbon steam reaction takes place to yield a reformed gas having a calorific value of approximately 350 Btu per cu ft. This is further enriched with additional refinery gas.

This will be Humphreys & Glasgow's third state opening in Australia. In 1953 the Premier of Queensland opened a gas plant built by the company at Brisbane; and in 1959 a plant at Launceston was opened by the Premier of Tasmania.

Geelong, with a population of over 100,000, is Victoria's second largest city. Besides being a leading industrial centre, its port handles most of the State's exports in wheat and wool.

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IMPROVED SIEVE PLATES FOR LOW-TEMPERATURE DISTILLATION

An account of how the trays of a low-temperature oxygen plant air distillation double columns was modified to get greater throughput. The choice before the designers was to increase the dimensions of the downcomer of a tray or to install two per plate. The latter course was adopted, the ratio between perforated to unperforated areas of the plate being 6:1. The output as a result was increased from 3000 to 3500 Nm^3O_2/h, and performance criteria described early on in the paper were met satisfactorily

by SLAVOJ JUSTA and LADISLAV KULE

IN equipment for the large-scale production of oxygen by low temperature rectification of air, the rectifying columns are usually fitted with sieve plates. Practical experience obtained during the operation of such units shows that the choice of the dimensions and the design of the tray downcomers are exceptionally important. An unsuitable design of the downcomer has a markedly unfavourable effect on the efficiency of oxygen production and at the same time limits—sometimes to a marked degree—the production capacity of the oxygen unit. The effect of the sieve design on the technology of oxygen production and on the output of oxygen plants will be illustrated in this article by a specific example obtained during a check of the functioning of a low-pressure column of throughput 3000 Nm^3 O_2/hr, which is part of an oxygen unit with a high-pressure air circuit. This plant example, as well as experience obtained in a large Czechoslovak hydrogenation factory, show what marked improvement can be attained by a simple modification of the downcomers on the basis of a theoretical analysis.

Brief Description of the Process Technology*

The separation of atmospheric air into technically pure oxygen and nitrogen is carried out by distillation in a system using a pressurized and low-pressure column. The lower column works at a pressure of 5.5 atm and the upper at a pressure of about 1.3 atm. Here the middle part of the unit, usually called the main condenser, fulfils the function of a deflegmator for the lower column and simultaneously a reboiler for the upper column. The feed to the lower column (1) is formed for the main part from compressed air, cooled in regenerators to about −171°C. Only a small part of the feed (6-8 per cent) consists of high-pressure air at 150-200 atm which was successively cooled in heat exchangers to −150°C, so that after expansion through the throttling valve it enters the pressure column as an equilibrium mixture of liquid and vapour. This column has only an enriching section. The liquid residue from the pressure column (2) containing 37 mol per cent O_2 enters the upper low pressure column after passage through a ceramic filter, sub-cooler and throttling valve as the feed (3). The condensate obtained from the main condenser by partial condensation of the crude gaseous nitrogen forms the reflux for the lower and also for the upper column (5). The distillate (4) from the lower column passes through the auxiliary condenser, where it undergoes further partial condensation.

The liquid phase thus obtained (7) is used as reflux for the upper column, while the vapour phase (9) after passage through cold exchangers and expansion in an expansion turbine is withdrawn from the system as two streams: (a) independently through exchangers as the pure nitrogen fraction containing 0.1 mol per cent O_2 and (b) in admixture with waste nitrogen from the upper column to the regenerators.

The liquid residue (10) from the upper column consists of technically pure oxygen (97-98 per cent O_2). The liquid oxygen enters the auxiliary condenser where, except for a very small fraction, it vaporizes. After passage through the acetylene trap in which oxygen droplets are separated from the gaseous phase, the gaseous oxygen (11) enters the regenerators. The distillate from the low-pressure column (12), consisting of crude nitrogen containing up to 3 per cent O_2, is employed for sub-cooling the feed to the upper column before entering the regenerators.

Enthalpy Balances

A prerequisite for calculating the hydrodynamical relations in the column is a knowledge of the flow rates on the individual plates of the rectifying column. For this reason it is necessary to carry out a graphical solution of the distillation process on an enthalpy-concentration diagram. In contrast to normal distillation calculations in single column units the calculation for this process is somewhat more complicated. Despite the fact that in subsequent calculations our attention will be focused purely on the hydrodynamical processes in the low-pressure column it is

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necessary first of all to carry out an enthalpy calculation for the system consisting not only of the low-pressure column but also of the pressurized column, the auxiliary condenser and the sub-cooler for the oxygen-nitrogen liquid mixture (Fig. 1). The reasons for this are clear in view of the interconnections of the various elements in the process unit. The upper column, for example, does not have a deflegmator and works with external reflux, which is formed partially by condensate obtained in the main condenser by deflegmation of the crude nitrogen from the pressure column and partially by condensate resulting from partial condensation of the distillate of the pressure column. The state of the feed for the upper column depends on the operating conditions of the lower column, on regulation of the ratio between the reflux of the lower column and the excess withdrawn as reflux to the top of the upper column, and finally it also depends on the functioning of the sub-cooler.

In Table I a summary is presented of the various streams discussed above, giving their specific amounts referred to 1 kg mol of distillate in the low-pressure column (X kg mol/kg mol), the enthalpy of the stream (H kcal/kg mol) and finally the enthalpy of the stream per kilogram mol of distillate in the low-pressure column (HX kcal/kg mol).

The calculation is shown in the diagram on Fig. 1. Section lines are denoted on the figure by dot-dash lines and auxiliary lines are shown dashed. The states of certain streams are denoted by ordinal numbers whose significance is clear from Fig. 2. If the state of the material is denoted by a fraction (for example, $2A/3$), it relates to a process in an expansion valve. The number in the numerator of the fraction relates to the state ahead of the valve (5.5 atm) while that in the denominator, to the state after the valve (1.3 atm). A survey of the auxiliary points for the graphical solution of the system is presented in Table IA.

Pole Co-ordinates

Since in the system of the pressure and low-pressure column the reflux for the upper column is partially withdrawn from the reflux to the lower column, we introduce the concept of the reference enthalpy of the distillate for the lower column

$$H_D = \frac{0.584 \times 2020 + 0.083 \times 867}{0.667} = 1881 \text{ kcal/kg mol}$$

and that of the reference amount of distillate for the lower column

$$D = 0.584 + 0.083 = 0.667 \text{ kg mol.}$$

This reference state is denoted on Fig. 1 by the point R. The position of the pole P_1 of the pressure column which is only an enriching column is determined by the intersection of the straight line going through states 1 and 2 and the ordinate passing through point R. The ordinate of the pole has the value 3550 kcal/kg mol. The amount of heat transferred in the main condenser per kg mol of distillate in the lower column is

$$q_R' = 3550 - 1881 = 1669 \text{ kcal/kg mol.}$$

The amount of heat transferred in the main condenser per kg mol of distillate in the upper column is

$$Q = q_R' \cdot D = 1669 \times 0.667 = 1113 \text{ kcal/kg mol.}$$

The amount of heat transferred in vaporizing the liquid oxygen in the upper column based on 1 kg mol of liquid oxygen is

$$q_W'' = Q/W = 1113/0.28 = 3975 \text{ kcal/kg mol.} \quad \ldots . (1)$$

The ordinate of the pole P_3 is given by the equation

$$H_{P_3} = H_W - q_W'' = 1964 - 3975 = -2011 \text{ kcal/kg mol} \quad \ldots . (2)$$

The pole of the enriching part of the upper column P_2 is determined by an analogous calculation. Its co-ordinates are $H = 2932$ kcal/kg mol and $Y_{O_2} = 0.044$ kg mol/kg mol.

Design of the Low-pressure Column

The upper column of the oxygen unit contained 36 sieve trays. These trays are of the type usual for low-temperature distillation equipment. The feed for the upper column is introduced on the 22nd plate counting from the base of the column. The actual surface of the plate consists of an annulus of external diameter of $d_e = 1800$ mm, and internal diameter $d_i = 600$ mm. The diameter of the openings is $d_0 = 0.9$ mm and their pitch $t_0 = 3.25$ mm. The liquid is forced to follow a circular path over the surface of the annulus. The ratio between the perforated and the unperforated area is 8 to 1 so that the active surface of the column amounts to 89 per cent of the total area. The overflow weir maintains a minimum height of liquid of $z_1 = 16$ mm on plates lying above the feed and $z_1 = 6$ mm below the feed. The disengaging downcomer is beyond the weir and through it the liquid passes to the next lower plate. By its design this downcomer simultaneously forms a liquid trap separating the spaces above and below the given plate. The minimum cross-section through which all the liquid flowing from a plate must pass has an area of $br = 55.4 \times 1.3 = 72$ cm^2 (see Fig. 3). The distance between plates $x = 90$ mm. Since, on increasing the throughput above 3040 Nm^3 O_2/hr, this column floods, a check calculation was made on the size of the plate downcomers. Empirical relations used for the calculation of the hydrodynamic régime on sieve plates were published by AKSELROD *et al.*[1, 2, 5] The calculation procedure was studied in the U.S.S.R. in the All Union Scientific Research Institute for Oxygen Producing Machinery (VNIIKIMAS).

Downcomer Dimensions

The calculations are carried out for characteristic sieve trays in the column, that is, for the highest plate of the enriching part (number 36), the lowest plate of the stripping section (number 1) and the feed plate (number 22). From Fig. 3 it is clear that the height of the lower edge of the downcomer trap is determined by Equation (3):

$$z_2 = r + a \text{ mm.} \quad \ldots . (3)$$

The height of the hydraulic seal a is usually chosen in the range 5 to 10 mm. The amount of liquid which flows through the downcomer is proportional to the cross-section. The relation between the specific throughput per unit width of the overflow weir and the minimum dimension of the overflow is expressed by the empirical equation

$$r_{2min} = A\sqrt[3]{(L/b)^2} \quad \ldots . (4)$$

For weirs of the type described, the coefficient A has the value 0.95. In order to avoid flooding we must have

$$z_2 > z_{2min}.$$

As is clear from the results of the calculations summarized in Table II, this condition is not fulfilled for the throughput 3040 Nm^3 O_2/hr at the feed plate and in the stripping section of the column. Thus the downcomers of the trap in the stripping section of the column cannot pass the necessary amount of liquid at this loading. The level on the sieves rises markedly and the liquid dumps through some of the openings in the sieve. This liquid dumping is aided by the relatively low velocity of the vapour in the sieve openings, which velocity approaches the limiting minimal value. This state, which according to direct observation is characterized by a strongly increased hydraulic resistance of the column (over 85 mm Hg) and a decreased plate efficiency, is very unstable and on further increase of the throughput flooding occurs very easily, leading to process upsets. The liquid cannot overflow in the required amount to the lower plate, but accumulates on the sieves and the liquid level in the reboiler rapidly falls.

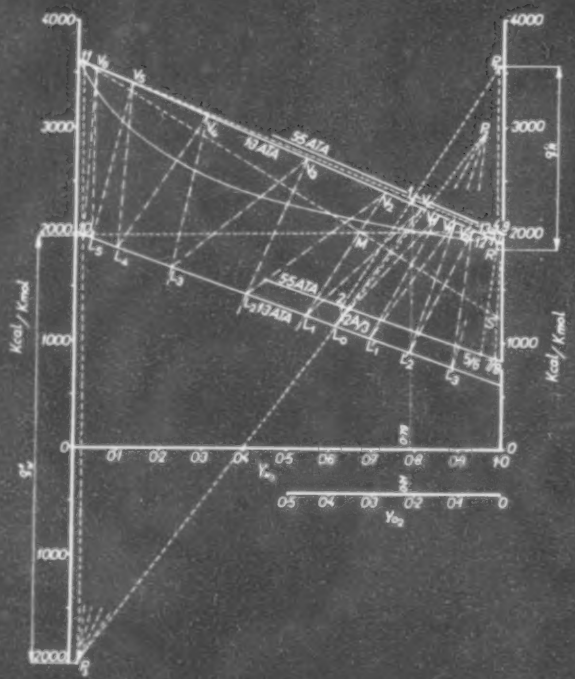


Fig. 1. H-Y diagram for low-temperature air rectification.

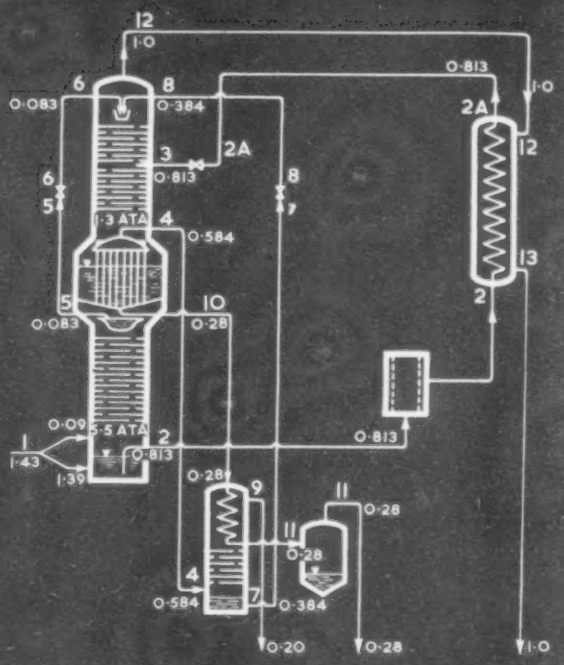


Fig. 2. Rectifying column flow sheet.

Hydraulic Resistance of the Sieve Plates

The hydraulic resistance of the sieves is given by the sum of the resistances caused by the static pressure of the liquid column over the openings, by the action of the liquid surface tension and by the flow of vapour through the sieve openings.[1]

$$h_s = h_{st} + h_\sigma + h_\delta = (0.195 \,.\, z_1 + 0.69 \,.\, h_1) \,.\, \gamma_k/\gamma_{H_2O} + \frac{4\sigma}{9.81 d_0} + 1.83 w_0^2 \gamma_g/2g \text{ mm} \quad \ldots.(5)$$

The height of the layer of liquid above the overflow weir is a function of the specific loading of this weir by liquid and was found empirically to be

$$h_1 = \sqrt[3]{\left(\frac{L}{bm}\right)^2} \text{ mm} \quad \ldots.(6)$$

Equation (6) agrees very well with the plant results, as is also true of the data presented in Table III.

Distance between Sieve Plates

In determining the necessary distance between the plates we must remember that above the layer of liquid a layer of foam occurs and that above it there is a certain volume filled with turbulent droplets carried up from the foam.

The height of liquid and foam on the plate during the distillation of air is given by the equation

$$n = z_1 + 3.53 h_1 \quad \ldots.(7)$$

To ensure a stable régime on the plate it is necessary to choose the actual distance between the plates to be greater than the sum of the heights of the liquid and foam and of the minimal empirically determined height of the free space

$$x > n + c = n + 20 \text{ mm} \quad \ldots.(8)$$

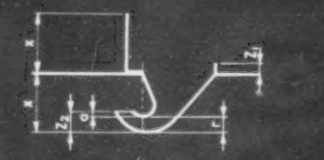
This distance must simultaneously be greater than the minimal height necessary for the correct functioning of the downcomer. For a given type of plate this condition is expressed by the empirical equation

$$x > 1 = 1.25 \left[1.71 z_2 - z_1 - 0.76a + 0.95 \frac{h_s}{\gamma_k} + 0.73 \left(\frac{L}{b(z_2 - a)}\right)^2\right] \text{ mm} \quad \ldots.(9)$$

As can be seen from Table IV, in the case of the plates being considered these conditions were also not fulfilled adequately.

Choice Between One- and Two-pass Plates

The distillation column bottleneck can be removed either by increasing the dimensions of the downcomer or by installing two downcomers per plate. From the point of view of maximum increase of throughput, it would clearly be desirable to have only one downcomer per plate with, however, such increased dimensions as would without hindrance ensure the capacity of the downcomer for the increased amount of liquid. If we were to choose two downcomers instead of one per sieve plate, we would have to remove a segment of the active perforated surface of the plate and replace it with a second downcomer, that is, with an element which for the actual diffusion process is valueless. This decrease of the active surface of the plate naturally leads to a proportional decrement of the optimum capacity of the plate. Even though the choice of two downcomers when judged exclusively from the point of view of attempting to achieve maximum utilization of the plate seems unsuitable, in the case of large industrial production units it nevertheless presents significant advantages. As a result of the forced circular motion of the liquid on the distillation plate, centrifugal forces which markedly disturb the uniformity of liquid distribution over the area of the sieve arise and lead to accumulation of liquid at its external boundary. The gradient of the liquid level on the sieve is the more apparent the greater is the distance of the given segment of the sieve from the overflow weir. In addition to the non-uniformity in the radial direction caused by cen-



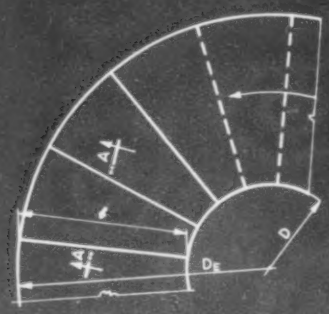


Fig. 3. Details of tray layout.

trifugal force, a further liquid gradient occurs on the plate in the direction of the flowing liquid. The liquid layer is highest at the entrance weir at the beginning of its motion along the plate and lowest at the downcomer at the end of its motion. The difference of levels depends on a number of factors, but above all on the loading of the overflow weir by liquid and on the length of the liquid path along the sieve. Non-uniformities in the liquid distribution over the surface of the plate can lead to the result that even with plates with apparently correctly chosen dimensions and vapour velocities in the sieve openings, limiting of the vapour flow through the sieve openings and even liquid dumping can occur on certain sections of the plate as a result of a strongly expanded liquid layer.

With two downcomers on the distillation plate the sieve area is divided into two sections. Since the length of the path of the flowing liquid on the plate is shortened and the loading of the overflow weir is decreased, the causes of large non-uniformities in the liquid level distribution over the surface of the sieve are substantially decreased. In each downcomer, or rather in the liquid seal, a certain deceleration of the motion occurs and hence a calming of the liquid. Beyond the weir the level is again equalized. By doubling the number of downcomers the calming effect is clearly increased.

The choice of a two-pass plate is to be recommended only if after dividing the plate the loading of the overflow weir does not fall below 7 m³ of liquid per hour per running metre of weir.[1]

In the reconstruction of our column, distillation plates were used having two downcomers. The minimum flow cross-section of the two downcomers was $2br = 2 \times 554$ mm $\times$ 16 mm = 177.3 cm². The height of the overflow weir was chosen the same for all plates at 10 mm. The ratio between the perforated and non-perforated area was 6:1. The dimensions of the plate downcomer were chosen so that even for the increased throughput of 3500 Nm³ O_2/hr they satisfied the previously cited criteria. Table V presents the key values for the plates. The assumed increase of the capacity of the plate was later substantially exceeded in practice.

Symbols Used

a = height of downcomer seal (see Fig. 3), mm;
b = length of downcomer weir, mm;
c = minimum height of free space above level of liquid, mm;
d_e = external diameter of sieve plate annulus, mm;
d_i = internal diameter of sieve plate annulus, mm;
d_o = diameter of sieve openings, mm;
g = acceleration of gravity, 9.81 m/sec₂;
h_s = overall hydraulic resistance of sieve, mm H_2O;
h_{st} = hydrostatic pressure, mm H_2O;
h_δ = dynamic resistance of sieve, mm H_2O;
h_σ = resistance caused by action of liquid surface tension, mm H_2O;
h_1 = height of liquid level above overflow weir, mm;
l = minimum height of weir (Equation (9)), mm;
m = coefficient in Equation (4):
= 6400 for $L/b < 5$ m³/m;
= 10,000 for $L/b > 10$ m³/m;
n = height of liquid and foam on plate, mm;
q_W = reboiler heat duty, kcal/kg mol vaporized;
q_R = condenser heat duty, kcal/kg mol condensed;
r = height of the narrowest flow cross-section of downcomer, mm;
t_0 = hole pitch on sieve, mm;
x = distance between plates, mm;
w_0 = vapour velocity in sieve openings, m/sec;
w_{min} = minimum vapour velocity in sieve openings, m/sec;
z_1 = height of overflow weir, mm;
z_2 = height of downcomer trap, mm;
A = coefficient in Equation (2);
D = amount of distillate, kg mol;
H = enthalpy, kcal/kg mol;
H_D = distillate enthalpy, kcal/kg mol;
H_W = liquid residue enthalpy, kcal/kg mol;
L = liquid flow rate, m³/hr;
L_n = liquid on nth theoretical plate in equilibrium with vapour, V_n;
L_n, L_n' = liquid on nth plate of stripping or enriching section of column;
M = mass flow rate, kg/sec;
P = pole;
P_1 = pressure column pole;
P_2 = pole for enriching section of upper column;
P_3 = pole for stripping section of upper column;
Q = heat added, kcal/kg mol;
V_n = vapour on nth theoretical plate in equilibrium with liquid, L_n;
W = amount of liquid residue, kg mol;
X = amount of constituent per kg mol of distillate from upper column, kg mol/kg mol;
Y_{O_2}, Y_{N_2} = mol fraction of O_2 or N_2, kg mol/kg mol;
γ_a, γ_k = specific weight of vapour or liquid, kg/m³;
δ = liquid surface tension, dyne/cm.

Indices

(l) = liquid phase;
(g) = vapour phase.

Check of the Actual and Permissible Minimum Vapour Velocity in the Sieve Openings

The true vapour velocity in the sieve openings must be larger than the limiting velocity w_{min} for which liquid dumping through some openings in the sieve just begins to occur. The value of the limiting minimum velocity of the vapour depends on the properties of the liquid (surface tension, viscosity, specific weight), on the height of the liquid layer, on the vapour properties and on the size and layout of the sieve openings.

The liquid will dump through the openings in the sieve when the weight of the liquid column above the opening is greater than the total force acting, which includes the effect of liquid friction on the wall of the opening, the effect of surface tension of the liquid, and the change of vapour momentum on flowing through the sieve opening.

AKSELROD derived, on the basis of a correlation of the experimental data for the calculation of the limiting velocity, a simplified relation whose validity is limited to the range of conditions normal during distillation of air.[1] On comparing this empirical equation with the basic theoretically derived equation for equilibrium of forces,[6] it is clear that the effect of surface tension is implicitly included in the expression giving the weight of the liquid column over the opening. The change of momentum of the flowing vapour which can be generally expressed as the product of the mass flow rate and the change of momentum $M(w_2 - w_1)$ is equal in the limiting case to $M(w_{min} - 0)$. The force balance is expressed by Equation (10):

$$M(w_{min} - 0) = \frac{\pi d_0^2}{4} w_{min} \frac{\gamma_g}{g} (w_{min} - 0) =$$

$$\zeta \frac{\pi d_0^2}{4} (0.85 z_1 + 0.47 h_1) \gamma_k / \gamma_{H_2O} \qquad \ldots . (10)$$

This equation simplifies to the form

$$w_{min} = 0.67 \sqrt{\frac{g \Delta h}{0.93 \gamma_g}} \quad \text{m/sec} \qquad \ldots . (11)$$

using the empirically determined value of the coefficient ζ. The vapour velocity in the openings of the modified plate satisfies the condition $w > w_{min}$ as shown in Table VI.

Plant Results

When the oxygen units fitted with the old-type sieves attained the limiting value of throughput of 3040 Nm^3 O_2/hr, they produced oxygen containing 96.7 to 97.0 per cent O_2 with an oxygen yield of 80 to 82 per cent.

After carrying out the above-described modifications in plate design, the operating parameters in Table VII were attained. Even on further increase in the throughput the distilling column operated without bottlenecks. A peak load of 4000 Nm^3 O_2/hr was attained. Under these operating conditions bottlenecks occurred in other parts of the system which could not be removed without major constructional changes. The measured hydraulic resistance of the column corresponded to the calculated values, and on increasing the throughput did not change substantially.

TABLE I

Stream	Yo_2 kg mol/ kg mol	X kg mol/ kg mol	H kcal/ kg mol	HX kcal/ kg mol
1 entrance of air into system	0·209	1·480	2327	3445
2 liquid exit from pressure column	0·368	0·813	1328	1080
3 feed to upper column	0·368	0·813	1230	1000
4 $N_{2(g)}$ exit from pressure column	0·010	0·584	2020	1180
5, 6 $N_{2(l)}$ reflux for upper column	0·050	0·083	867	72
7 $N_{2(l)}$ exit from auxiliary condenser	0·014	0·384	833	320
8 $N_{2(l)}$ entrance to upper column	0·014	0·384	833	320
9 $N_{2(g)}$ exit from auxiliary condenser	0·002	0·200	2000	400
10 $O_{2(l)}$ exit from main condenser	0·985	0·280	1964	550
11 $O_{2(g)}$ exit from auxiliary condenser	0·985	0·280	3607	1010
12 $N_{2(g)}$ exit from upper column	0·033	1·000	1955	1955
13 $N_{2(g)}$ exit from sub-cooler	0·033	1·000	2035	2035

TABLE IA

Addition Point	For States	Of Co-ordinates Yo_2 mol/mol	H kcal/kg mol
M	4—10	0·326	2002
M	11—S	0·326	2002
N	9—13	0·028	2029
R	4—5/6	0·015	1881
S	7/8—9	0·010	1233

TABLE II

Plate Number		36	22	1
z_{2min}	mm	17·4	24·5	22·6
z_2	mm	20·0	20·0	20·0

TABLE III

Plate Number		36	22	1
h_s	mm	26·8	27·5	28·0

TABLE IV

Plate Number		36	22	1
$n + c$	mm	79	100	90
l	mm	67	101	85
x	mm	90	90	90

TABLE V

Plate Number		36	22	1
z_{2min}	mm	13·1	18·3	17·4
z_2	mm	22·0	22·0	22·0
$n + c$	mm	64	81	75
l	mm	79	74	66
x	mm	90	90	90

TABLE VI

Plate Number		36	22	1
z_1	mm	10	10	10
L/b	m^3/mh	7·65	17·6	14·2
h_1	mm	9·55	14·5	12·6
w_{min}	m/sec	3·06	3·56	3·74
w_0	m/sec	6·00	5·05	4·85

TABLE VII

O_2 throughput	Nm^3 O_2/hr	3800
O_2 purity	vol % O_2	98·3
Total air consumption	Nm^3/1000 Nm^3O_2	5246
O_2 yield	%	89·7

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* The numbering of the various streams cited in the text is identical with that used in Figs. 1 and 2. From these figures it is also possible to read off data on the amount, composition and enthalpy of the appropriate streams.

Czechoslovakian Chemical Engineering Conference

SOME 130 papers covering many branches of chemical engineering, equipment design and automatic control were presented at a conference held by the Chemical Engineering Section of the Chemical Society of Czechoslovakia. The conference, which took place at the spa of Luhacovice early in October, was attended by more than 500 engineers, including a large group from East Germany and a smaller group from the U.S.S.R. Within the space of a few words, adequate reference to the many papers presented is not possible, but it was evident from their content that a great deal of attention is being given by the countries represented to such matters as the supply of equilibria data for systems of industrial importance, to problems of reaction kinetics and mechanisms, to optimization and, in particular, to equipment design. There were also signs of a rapidly growing school of chemical engineering science in Czechoslovakia, its leading exponent being PROFESSOR G. STANDART of the Czechoslovakian Academy of Sciences.

In company with a number of co-authors, Professor Standart presented several papers at this conference. These ranged over the spheres of multi-component diffusion, relationship between HETP and HTU and the efficiency of various types of mass-transfer device, including grid trays.

DR. GELBIN, of the large chemical works at Leuna, East Germany, was also prominent at the conference, as author and co-author, with papers covering a number of topics such as the kinetics of catalytic reforming with platinum catalysts, the thermodynamics of three-phase equilibria, and the calculation of ammonia synthesis reactors by means of an electronic computer.

From the U.S.S.R. one of the most interesting papers was given by V. OLEVSKY on the performance of trickle plate columns for high vacuum distillation. This paper aroused a great deal of discussion, to which another authority on this type of column, G. ADOLPHI, of Leuna, contributed meaningfully.

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PART III

THE STATUS AND REMUNERATION OF THE PROFESSIONAL MAN IN INDUSTRY

It is shown that the professional employee, at the start of his career, ought to expect considerable increases in remuneration and status. Instead, he has to work at an ever-higher level of experience and responsibility merely to maintain his position. It is further shown that he is losing ground continually, not because of income taxation as appears to him, but because increases for economic factors are determined by manual employees' wage rates instead of by their earnings. There is thus no incentive for the individual professional employee to utilize his experience and to carry greater responsibility.
The article further discusses how changes in "basic week" and "paid holidays" affect the status between professional and manual employees

by M. DAVIDMANN

Changes in Status in the Course of Time

WE are here concerned with the individual's changes in remuneration and status, throughout his life. We thus use the dynamic status equations. Status is measured by the remuneration ratio and may be computed from remuneration received by the individual either before or after deducting income tax. Status is normally measured by remuneration before deducting income tax, but is here evaluated also for remuneration after deduction of income tax, so as to evaluate the effect of this taxation on the status of the individual. We are considering employees only, that is those whose main, and mostly sole, income is derived from full-time employment.

Two grades of chemist are considered in relation to a manual employee whose remuneration is assumed to correspond to earning the average weekly earnings[9] for 52 weeks per year. The two grades considered are G25 and G75, corresponding to moderate and considerable success respectively.

The individual in each case is assumed to be married at age 27, the first child being born in the fourth year after marriage, the second child being born in the seventh year after marriage. He is 40 years of age in 1959, and thus marries during 1946, the two children being born in 1950 and 1953 respectively. He remains married during the entire period we are considering, which is from 1949-69.

In calculating income tax, it is assumed that the remuneration received consists entirely of earned income. The appropriate earned income, single or married personal and child allowances are given. Up to 1960 the known rates and bands of allowances, tax and surtax were used; from 1960-69 those applicable in 1960 were assumed. The wife was assumed to have no income and factors such as family allowance or national insurance contributions were not considered.

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It is assumed that b and the x_0 distribution remain constant throughout the period being considered, that is from 1949-69, this having been shown to be the case for the period 1953-59, the level of b being 1265. The compound rate of change, i_p, was found to be 5.9 and 4.4 per cent per year over the period 1956-59, for chemists of grade G25 and G75 respectively. It is here assumed that these rates of change apply throughout the period being considered. The data used for estimating the remuneration of chemists are those obtained from the 1959 remuneration survey, as follows:

Grade	G25	G75
x_0	53·4	61·0
y_{or}(£)	1630	2930

We have seen that the remuneration of manual employees (all industries, all operatives) increased at an average compound rate of 6.9 per cent each year during the period 1946-59. It is here assumed that this rate applies over the period 1949-69. The average weekly earnings in 1938 were 53s. 3d. and, assuming this is earned for 52 weeks of the year, we have

$$E_R = \frac{52 \times 53.25}{20} = £138.5 \text{ p.a.}$$

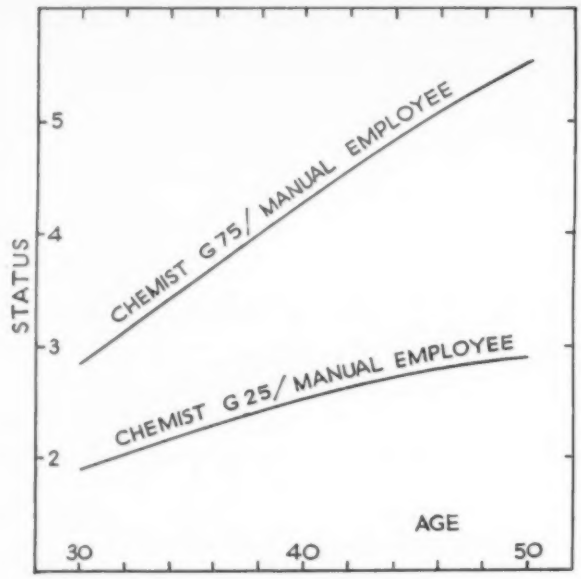
The equation of the straight line which correlates the index of average weekly earnings (Fig. 21) is:

$$\log_{10} I_{mn} = 0.2399 + 0.02902\ (T_n - 1945) \quad \ldots . (46)$$

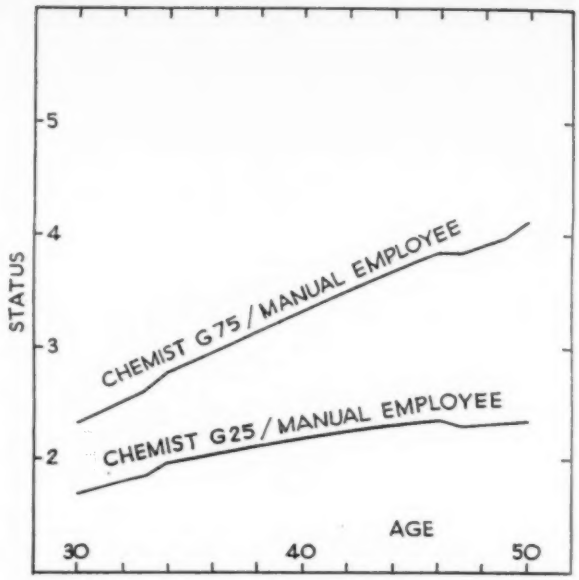
Hence the remuneration of the manual employee may be calculated from Equation (35), since

$$E_n = E_R I_{mn} \quad \ldots . (35a)$$

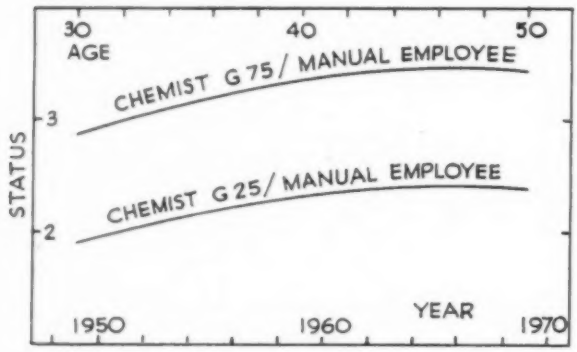
Thus during 1949 the manual employee received a remuneration of £314. The remuneration of the chemists may be calculated for the year 1959, for each grade, from Equation (5a). From Equation (7) we have



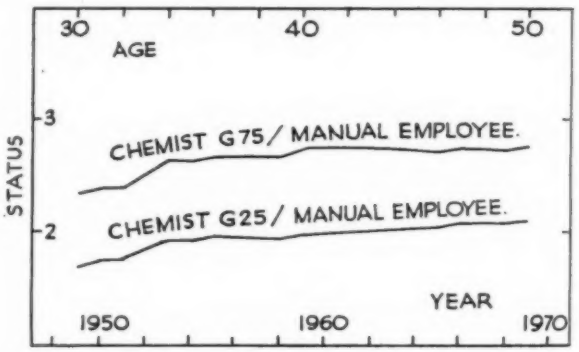
23 *Static status for year 1949 based on earned income before deducting income tax.*



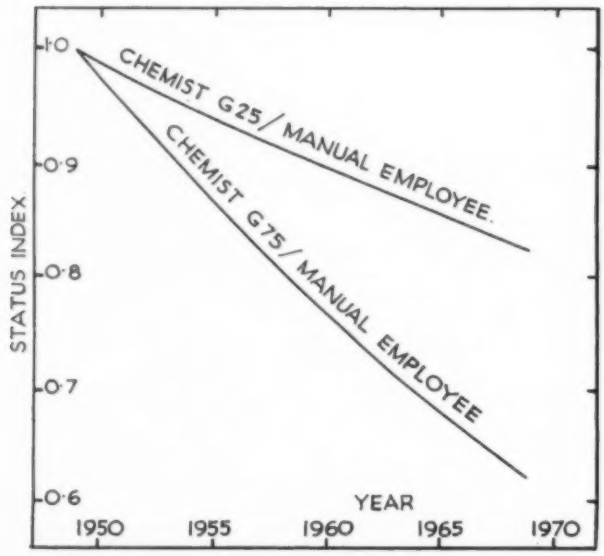
24 *Static status for year 1949 based on earned income after deducting income tax.*



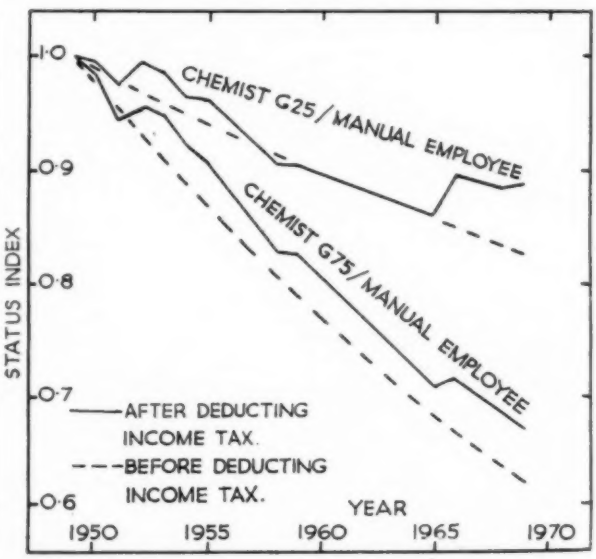
25 *Dynamic status based on earned income before deducting income tax.*



26 *Dynamic status based on earned income after deducting income tax.*



27 *Status index for professional relative to manual employee, based on earned income before deducting income tax.*



28 *Status index for professional relative to manual employee, based on earned income.*

$$\frac{y_{0n}}{y_{0r}} = (1 + i_p)^{T_n - T} \qquad \ldots . (7a)$$

and hence the remuneration of the chemists, at any specific age, is 0.564 and 0.652, in 1949 of that in 1959, for grades G25 and G75 respectively. Knowing the remuneration of the chemists and of the manual employee in 1949, we may then calculate static status for the year 1949 by Equation (16), and we may do this both before and after deduction of income tax.

The results of such calculations are illustrated by Figs. 23 and 24, before and after deducting income tax, respectively. Higher remuneration is taxed to a greater extent than lower remuneration and to that extent status after tax deduction is somewhat lower than before tax is deducted, and the higher the remuneration the greater is the reduction of status due to income taxation. This is as expected. However, the significant feature which is common, no matter whether status is considered before or after tax deduction, is that the chemist in 1949 could look at his equals and expect very considerable increases of remuneration and of status, as he grew older, as a reward for increased experience and responsibility carried, in accordance with his grade.

We may now consider what happens as the individual grows older. The remuneration of the manual employee can be calculated from Equation (35a) and that for the chemists from Equation (8a). The ratio between them (Equation (22)) gives the dynamic status, which could have been calculated from Equation (23) had we not been concerned with deduction of income tax.

The results of such calculations are illustrated by Fig. 25 for remuneration as earned, and by Fig. 26 for remuneration received after deduction of income tax. Consider Fig. 25. The chemists' status, before deducton of tax, appears to increase, in accordance with expectations, as the individuals grow older. But Fig. 26 shows that to the individual it appears that the effect of taxation is to counteract and nullify any increase in status from about age 34 onwards. The individual professional employee feels that he must work at a constantly higher level, carrying increasing responsibility, receiving an ever-higher remuneration, in order just to maintain his position in society, and that this state of affairs is caused by the incidence of income taxation. The individual feels that it is income taxation which is depressing the status of the professional employee. This, then, is the subjective situation.

Actual changes in status, however, are measured by the status index. The status at any particular year is given as a ratio to that for the same age in the reference year. The status index may be evaluated by using Equation (26) when considering remuneration before deduction of income tax, and Equation (24) when considering remuneration after income tax has been deducted. Fig. 27 shows how in fact status changes over the period being considered. The index indicates that status of professional relative to manual employees is falling steadily throughout the period, when remuneration before deduction of tax is considered. Fig. 28 shows that the actual effect of taxation is to counteract to some small extent the erosion of status which is taking place. This loss of status is such that a chemist, 40 years of age in 1959 and of grade G75, his remuneration then being about £2070 p.a., would require an increment of £560 in 1959, in addition to what he is receiving, to restore his status to the 1949 level, not considering the effect of income taxation or any change in status between 1938 and 1949.

The status of the professional employee is continually decreasing. He has to work at an ever-higher level of responsibility merely so as to maintain his position in society, thus carrying greater responsibility without real reward. It is this which accounts to some considerable extent for the frustration felt at present by professional employees in industry. This loss of status is in no way caused by the incidence of income taxation, but is due to the fact that the professional employee does not receive sufficiently high increments to reward him for the additional responsibility carried and to give him an increased standard corresponding to that received by manual employees. No comment is made here on just what level of status ought to be maintained for professional relative to manual employees; but it cannot be emphasized too strongly that the redistribution of remuneration, that is, the reduction of status, is proceeding at such a pace that there is no positive incentive for the professional employee to carry greater responsibility, as he has to carry greater responsibility merely to maintain his position in society.

Changes in Remuneration of Individuals in the Course of Time

A salaried individual professional employee may compare his own progress with that of others of his own grade, not only between surveys, but year by year. He may do this by arriving at a realistic representation of his own remuneration and by comparing this with calculated remuneration over a few years. The only individual data required for carrying out the calculations, in addition to the National Remuneration Scale for his profession, are his age and remuneration in a particular year. What matters is how his remuneration continues to compare with others of the same grade.

In the first place a curve is drawn of remuneration against time. The remuneration scale is in £ p.a. and the time scale is given in years and months. This method of plotting remuneration is illustrated by Fig. 29 and it should be noted that it is an exact representation of earned income, the area under the curve representing remuneration received. It is the mid-points of the horizontal lines which have to be joined (Fig. 30) to show how remuneration is progressing. Where month-to-month data are not available, or not applicable, remuneration received per calendar or fiscal year, as the case may be, may be plotted against the year (Fig. 31).

The grade and its maximum remuneration (y_{0r}) is obtained from the National Remuneration Scale for the individual, and his remuneration may then be calculated by any of the dynamic remuneration equations given earlier on. The example illustrated by Figs. 29 to 31 shows such calculations made by means of equation:

$$Y_n = y_{0r} I_p \, e^{-(X_n - x_0)^2/b} \qquad \ldots . (47)$$

which is derived from Equations (5b) and (32a). The index of remuneration, I_p, is assumed to be equal to that for manual employees:

$$I_p = \frac{Y_n}{Y_r} = \frac{E_n}{E_r} = \frac{I_{mn}}{I_{mr}} \qquad \ldots . (48)$$

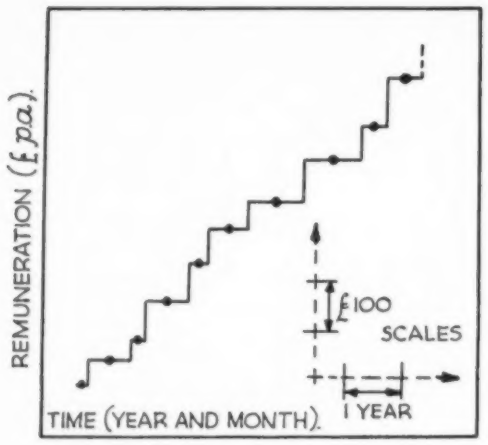
The particular index chosen is the index of weekly wage rates[10] as discussed previously, and the value of

$$e^{-(X_n - x_0)^2/b}$$

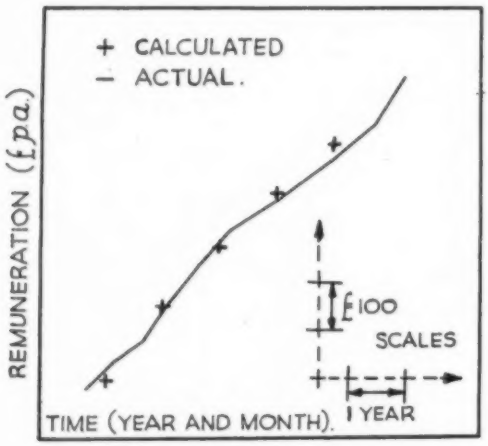
may be readily evaluated from a curve of the basic remuneration distribution, as given in Fig. 16.

One may quickly estimate one's own progress in relation to that of others of the same grade, using the data obtained by the last survey. This "*do-it-yourself*" method is, however, limited by the accuracy with which the data may be read from the curves provided. It is illustrated by Table VI. The example chosen for illustration is that of an engineer 45 years of age in 1955/56, then earning £1500 p.a. Fig. 12 gives his grade and his income as he grows older, assuming economic factors to remain constant. These are then allowed for by computing the index ratio and multiplying this by the income in the year of the survey.

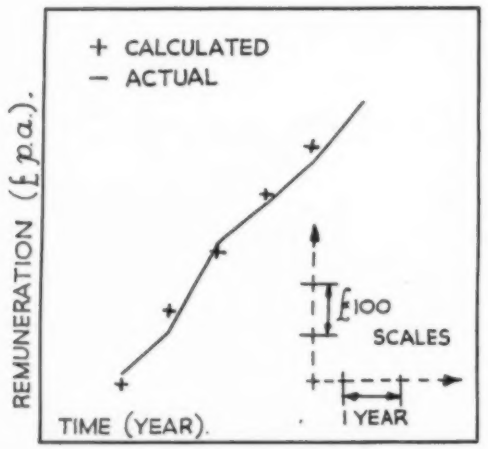
Inspection of Figs. 30 and 31 reveals that there is close



29 *Remuneration of an individual.*



30 *Comparison between remuneration received by an individual and by others of the same grade in the same profession.*



31 *Comparison between annual remuneration received by an individual and by others of the same grade in the same profession.*

correspondence between actual and calculated remuneration for the individual professional employee whose case is illustrated. He is receiving neither promotion nor demotion and progressing, on the whole, at the same pace as others in his grade. His remuneration may be calculated with very reasonable accuracy as long as he remains in his grade. A number of such calculations have been carried out and point to the conclusion that the index of weekly wage rates may be used with a reasonable degree of confidence in making such calculations where the basic remuneration scale is unaffected by changes in the supply versus demand pattern. The employer's attention is focused on negotiations concerning wage rates and his professional employees (including executive directors) receive corresponding increases. But we have seen (Fig. 21) that the manual employees' wage rates increase at about 5.4 per cent per annum, whereas corresponding earnings increase at about 6.9 per cent per annum, and it is this difference between wage rates and earnings, combined with professional employees receiving "cost-of-living" increments which correspond to increases in wage rates, which explains the falling status of the professional employee. On the other hand, should he be willing to accept the index of average weekly earnings, then his remuneration would depend to that extent on the state of the national economy, thus giving the professional employee some considerable stake, and thus incentive, in the well-being of the national economy.

JEWKES[8] has said that between 1939 and 1951 prices increased by 100 per cent. He cited the DANKWERTS award to support this figure. But MR. JUSTICE DANKWERTS' betterment factor of 100 per cent did not concern itself with prices, but with income.[18] Earnings of professional employees, and not prices, had increased by about 100 per cent. However, we have seen that the remuneration of professional employees has increased in accordance with wage rates for manual employees, but not in accordance with the earnings of manual employees. The indices[9] for 1951, based on a value of 1.00 for 1958, show that MR. JUSTICE DANKWERTS' betterment factor is in complete agreement with this. In 1951 the indices for manual employees were roughly as follows: wage rates: 2.02, earnings: 2.60, prices: 1.62.

Remuneration and Status

Some remuneration surveys are based on rate of earning at a specified date, others on income received during a fiscal year. A standard basis is required, particularly when remuneration is to be used for evaluating status. As long as one considers status as being measured by a remuneration ratio, it is income earned which matters and not a wage rate which, in the normal overall case, gives no guide on status.

The remuneration of the professional chemists surveyed[1, 2, 4] was that from salaried and/or professional services, that is the gross earned income. The individual's national insurance or superannuation contributions were not deducted, and his employer's superannuation contributions, where made, were not added. Retirement pension from previous employment was to be included. There also had to be included additional remuneration such as bonus, share in profits, allowances other than expenses, value of free quarters provided and remuneration derived from professional services consistent with but not part of the employment, such as from external examining or advisory work by a university teacher. The salary was to be that as at 1 April (1955) or 1 May (1956) or the earnings in the fiscal year ended 5 April. The Engineers Joint Council (U.S.A.)[12, 13, 14] considers that remuneration is the base salary including cost of living allowance, if any, plus bonus if considered part of salary, but not including payments for overtime work. The

remuneration survey for engineers[5, 8] analysed income during the fiscal year.

As regards computation of earned income, overtime should be included, as status is determined by total earned income. We know the cases of reluctance to transfer from an overtime-paying level of position to the next non-overtime paying higher level, where this results in some loss of income. Another case is that of engineers working on site, where the engineer who receives overtime works in many instances shorter hours and carries less responsibility than the senior engineer in charge, but receives the higher remuneration by virtue of his overtime payments.

It is total income (that is, earnings) which is a measure of status and not wage rates. Conditions of employment may be altered for manual employees by changes in the "basic week" worked. This is no more than an increase in earnings which is independent of wage rates. An increase in a wage-rate is comparatively unconditional, whereas a reduction in the number of hours which make up the basic working week is an increase in earnings which depends on the well-being of the economy. When the number of overtime hours worked each week remains constant, then earnings are increased; when less work is available, earnings fall.

A reduction in the working week for the salaried employee who receives pay for overtime means a similar increase in earnings which is conditional upon the work available. The employee in the more responsible position who receives no overtime pay has not gained, but lost. The amount of work is not reduced and his status, as measured by income, has been reduced by the reduction in working hours. Hence an increase in income earned by reduction in basic working hours for manual employees should be accompanied by a corresponding increase in remuneration for the non-overtime-paid employee, the salaried employee who receives pay for overtime being in a somewhat intermediate position, dependent on the regularity with which overtime is being worked.

As the carrying of responsibility is being paid for in the case of the professional employee, it follows that not only should he receive an increase corresponding to the increase in earnings which the manual employee receives as a result, but the number of hours worked by the professional employee should be reduced as well, corresponding to the reduction in hours of the basic working week. In the event of general economic misfortune, when no overtime is being worked, the manual employee falls back on to his basic working week. Where the professional employee's remuneration is dependent on the earnings of the manual employee, by using an index of average earnings for manual employees, the professional employee shares the misfortune of the manual employee, but cannot be asked to do this unless he has received the initial increase in remuneration as well as a reduction in working hours. Where the index of earnings is used to maintain the professional employee's status, compensation is automatic. The manual employee works a shorter basic week, the professional employee works a correspondingly shorter week. Any consequent gain in income by the manual employees is shared by the professional employee through adjustment of his income using the index of earnings, and both share equally in the state of the national economy, the professional employee lagging behind the manual employee to the extent of the time required to compile, publish and apply the index.

Another question which arises is that of holidays. When the holidays with pay of manual employees were increased, those of professional employees were not, as a rule, increased in proportion. It is suggested here that remuneration be expressed, for the purpose of comparison, as an annual income based on 52 weeks, as if all the income had been earned in the number of weeks actually worked, that is, earned in 52 weeks minus the number of weeks' holiday to which the employee is entitled. For example, an income of £500 in one year which included two weeks' holiday becomes £500 × 52/50, the remuneration received for the holiday period having been included in the initial £500.

Also included in remuneration received should be bonus payments, luncheon vouchers, an allowance for use of company's car and employer's contributions to a superannuation scheme.

Table VI.—Example of Estimating own Progress Compared with that of Others of the Same Grade

Basic Data

Profession:	Engineer
Year of survey:	1955/56 (Fiscal year)
Income:	£1500 p.a. in 1955/56
Age:	45 in 1955/56

Derived Data

Grade:	G60[1]

Age	Income in year of survey[1] (£ p.a.)	Fiscal year (T)	I_{mn} (note 2)	$\frac{I_{mn}}{I_{mr}}$ (note 3)	Income[4] in year T (£ p.a.)
(1)	(2)	(3)	(4)	(5)	(6) = (2) × (5)
45	1500	1955/56	2·55	1·00	1500
46	1540	1956/57	2·76	1·08	1600
47	1570	1957/58	2·89	1·13	1750
48	1600	1958/59	3·00	1·17	1870
49	1630	1959/60	3·07	1·20	1960

Notes

[1] From Fig. 12 for engineers (Fig. 11 for chemists).

[2] From Table VII (index of weekly wage rates). Could also be taken from Table VIII (index of average weekly earnings).

[3] 1955/56 is year of survey, i.e., is the reference year. Hence $I_{mr} = I_{mn}$ for 1955/56 = 2·55.

[4] This is how others of the same grade are estimated to progress. An income higher than that calculated indicates promotion to a higher grade, and vice versa.

Table VII.—Index of Weekly Wage-rates

Year	Index
1938	1·000
1946	1·633
1948	1·781
1949	1·828
1950	1·863
1951	2·020
1952	2·187
1953	2·289
1954	2·389
1955	2·549
1956	2·759
1957	2·892
1958	2·996
1959	3·071

Note: Based on data given in Ref. [9].

Table VIII.—Index of Average Weekly Earnings

Date	Index
1938	1·000
Oct. 1946	1·897
Apr. 1947	1·944
Oct. 1947	2·032
Oct. 1948	2·203
Oct. 1949	2·285
Apr. 1950	2·331
Oct. 1950	2·404
Apr. 1951	2.554
Oct. 1951	2·650
Apr. 1952	2·766
Oct. 1952	2·853
Apr. 1953	2·962
Oct. 1953	3·007
Apr. 1954	3·127
Oct. 1954	3·225
Apr. 1955	3·422
Oct. 1955	3·515
Apr. 1956	3·715
Apr. 1957	3·844
Apr. 1958	4·022
Apr. 1959	4·178

Note: Based on data given in Ref. [9].

The Environment

In an industrial civilization many needs arise for a large number of different products and services. These needs are satisfied by a correspondingly large number of specialized work units. This system of organization will succeed in meeting the society's needs only if all the following requirements are satisfied:

(1) The society's effort has to be divided into separate and distinct activities carried out in work units. Each work unit carries out an activity essential to the completion of the work, determined by the work undertaken. This division of work, to be effective, has to be functional.[11, 15, 17]

(2) Individuals and work units need to co-operate with each other to complete the work undertaken, that is, work together in teams for the benefit of society at large.[11, 15–17]

(3) Free competition is required between work units carrying out the same functional activity. This ensures that work is done efficiently.[11]

(4) Reward has to be in proportion to the service rendered and to the urgency of the need satisfied.

If any of these requirements is not met, then difficulties can be expected. Difficulties which occur when requirements (1), (2) or (3) are not met have been investigated and the analysis reported in the references indicated. This article deals with requirement number (4) above.

There is preoccupation amongst professional employees about salaries. It is felt that reward, in terms of salary and status, is out of proportion to the service rendered, compared with the reward given to other sections of the community for the services rendered by them. In other words, it is felt that the professional employee is losing status. To evaluate such a change so as to prove this one way or the other requires an analysis of work done by individuals, that is of service rendered. A comparison may then be made by comparing groups rendering equivalent service, or by evaluating how status changes with time. This presupposes the existence of a national scale of service and reward.

This article analyses the work and pay of the professional employee, illustrated by reference to chemists and engineers, and compares this with that of manual employees. It is shown that professional employees are in fact being paid according to a fairly rigid national scale of remuneration. It is a scale which determines reward in accordance with the responsibility carried. It, in connection with a similar scale at a different point in time, may be used to separate out how a particular individual or group has maintained his or its position within their own group or society at large, by allowing for changes due to increased or reduced responsibility.

The existence of an overall national scale of reward, which allocates reward in accordance with service rendered, raises a number of points. Reward should increase in accordance with the need satisfied, but one has to accept that it may decrease as the need diminishes. It remains to establish either that the need has changed or that internal conflict within the society interferes with the fair apportioning of reward. Should such conflict be present it would operate to the detriment of the society as a whole. As regards the professional employee, it is probable that, in a highly industrialized society, within a larger equally industrialized and competitive world, its welfare tomorrow depends on the reward, that is on status and thus on remuneration, given to its professional employees today.

The model of the economy described above draws attention to the need for teamwork between individuals or groups, reward adjusting itself freely in accordance with variations in the urgency of needs. Where this is not the case, difficulties may be expected. This article shows that it is the employers who are depressing the status of the professional employee without, undoubtedly, being aware of this, their attention remaining focused on wage-rates instead of being concentrated on earnings, or else by following a pattern of supply and demand which puts manual work at a premium. This has resulted in a reduction of incentive to carry responsibility, for the professional employee, to the extent that he must do work at an ever higher level of responsibility so as just to maintain his status, with consequent risk to the future prosperity of society at large. Again, no comment is made here on what is, or is not, a desirable status, but it is emphasized that the rate at which status is reducing is such that there is no positive reward for the professional employee for the increasing responsibility he carries as he grows older. Again we see that each single one of the requirements, given above as being basic to our industrial civilization, has to be satisfied, society as a whole being detrimentally affected when this is not so.

ACKNOWLEDGMENT

The author is indebted to MR. C. R. COLLEY, who read the manuscript and made many helpful suggestions.

33rd International Congress of Industrial Chemistry — France

FRANCE'S 33rd International Congress of Industrial Chemistry, held this year at Bordeaux from 1 to 8 October, was preceded by a three-day Chemical Engineering Meeting at the nation's first Chemical Engineering Institute at Toulouse.

Two important events marked the Toulouse meeting. First, was the official opening of the Institut de Génie Chimique itself, and then came the presentation of Honorary Doctorate Degrees to PROFESSORS D. M. NEWITT of Imperial College, London; B. F. DODGE of Yale University, U.S.A.; and K. G. DENBIGH of Imperial College, London.

France's Institut de Génie Chimique is directed by PROF. J. CATHALA and features two unusual characteristics. The first is the incorporation of a Technicians' School for the training of skilled technicians in parallel with that of chemical engineers. The second is the presence of an industrial ensemble at which students will operate and develop industrial processes on a semi-industrial scale.

Already in operation is a plant which produces 5 tons/day of liquid SO_2 from powdered sulphur by melting the sulphur and burning it under pressure by submerged combustion, followed by liquefaction. This process will be extended to include the high-temperature catalytic oxidation of SO_2 to SO_3 at high conversion rates, separation of SO_3 from unreacted SO_2 by fractional condensation, and the eventual production of 7½ tons/day of concentrated H_2SO_4.

Another process expected to be operating at the industrial ensemble is one to produce nitric acid from synthetic ammonia by catalytic conversion followed by oxidation of NO to N_2O_4 and vapour phase formation of HNO_3 which will condense to 70 per cent HNO_3 solution.

The relative merits of such plants at universities are the subject of some controversy. However, an essential element in overcoming the cost of these projects at Toulouse is the close collaboration between the Institut and the nearby plant of the Office National Industriel de l'Azote which supplies the sulphur raw material and purchases the liquefied SO_2.

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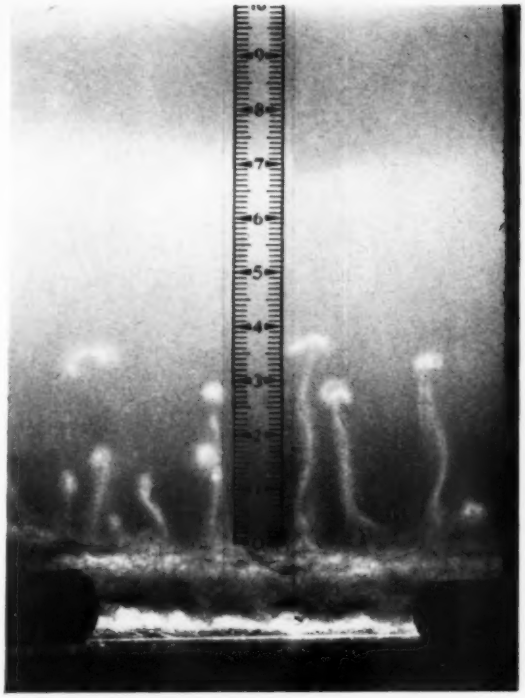
THE MECHANISM OF FLUIDIZATION

The mechanism of fluidization has been investigated and it has been found possible to reconcile the apparently different characteristics of gas and liquid fluidization. Hitherto unsuspected discontinuities and non-homogeneities in apparently uniform fluidized beds have been discovered, while partial voids (parvoids) and bubbles have been observed in liquid fluidized beds of alumina and of glass ballotini. Particulate fluidization occurs as a light phase in gas fluidization.

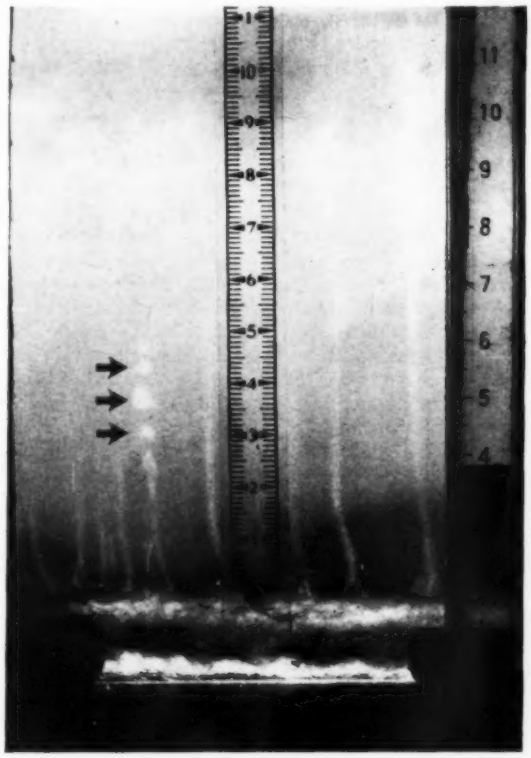
This article reviews the generally accepted concepts of gas and liquid fluidization behaviour and outlines the experimental findings of this investigation. Experiments are described which disclose the coexistence of labile fluidized and fixed regions in an apparently homogeneous bed, and their persistence into the bubbling stage.

by N. J. HASSETT



▲ 1 *Parvoid initiation. Glass ballotini* 76-104 μ. *Parallel plate apparatus* 10 × 0.5 *cm cross-section.*

2 ▼ *Channels under steady-flow conditions. Note mushroom-shaped parvoids in channel. Glass ballotini* 76-104 μ. *Parallel plate apparatus* 10 × 0.6 *cm cross-section. Superficial water velocity* 0.11 *cm/sec with superimposed pulses.*



THE term "fluidization" applied to a bed of solid particles implies the conversion of that bed from a settled state where it behaves as a coherent porous solid, to a state where it behaves as a fluid with properties of flow and surface levelling, and pressure/depth relationships. It implies, too, that each particle is independently mobile.

The ideal state of fluidization, where the whole of a bed of particles behaves as a homogeneous fluid is probably not attainable, and in practice the term is loosely applied to a bed of particles maintained to a large degree in a state of motion by an upwards current of fluid. Attempts to define or measure degree of fluidization have been made,[1, 2, 3] but the limitations are evident, and indeed it does not appear that any close definition applicable to all cases can be made.

The general picture presented by literature on this subject is that fluidization by gases follows a distinctly different path from fluidization by liquids. Prior to attainment of the fluidized state, however, the functioning is the same. A fluid passing vertically upwards through a bed of particles exerts a drag force on each individual particle, reducing its apparent weight. At some critical fluid velocity, the particles are just fluid-borne, i.e., effectively weightless, but remain quiescent and in contact with each other. This is the point of "incipient fluidization". Above this critical velocity,

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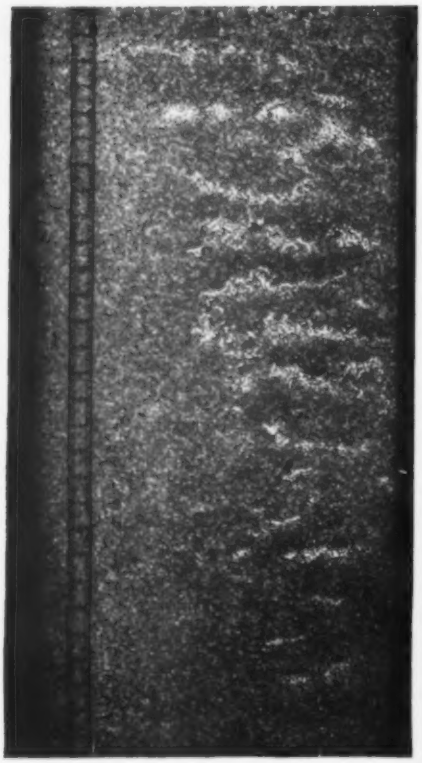
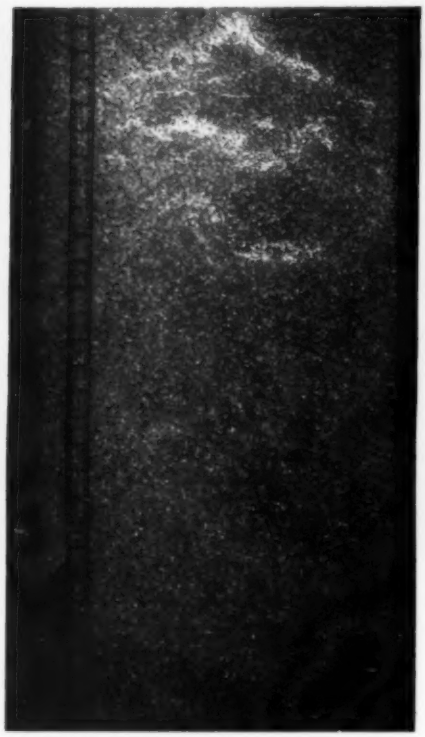
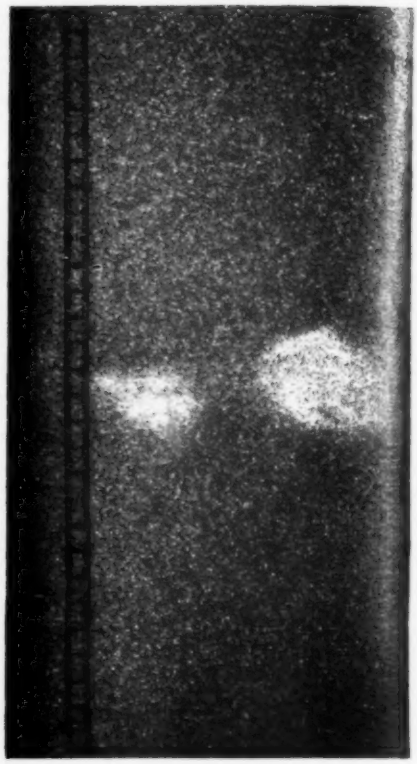


3 *Parvoid striæ at steady superficial water velocity 2.50 cm/sec. Blue glass ballotini 1200-1500 μ. Parallel plate apparatus 14 × 1.25 cm cross-section.*

4 *Single bubble injection. Superficial water velocity 1.45 cm/sec (just below breakthrough velocity). Blue glass ballotini 1200-1500 μ.*





5 *Bubble formation by single pulse injection. Parvoid completely disappears at height of about 25 cm.*

the bed becomes actively fluidized and follows a seemingly different pattern of behaviour according to the nature of the activating fluid.

The pre-fluidization stage is sometimes extended by the inclusion of an indeterminate period just preceding the point of incipient fluidization, when the particles are stated to realign or rearrange in such manner that the bed offers the maximum flow passage (voidage) to the fluid.[4] This period has been neglected, by and large, as being indeterminate, but it is part of the findings of this present work that it is an integral step in fluidization.

Where the activating fluid is a liquid, a greater flow rate than that for incipient fluidization results in an expansion of the bed. As the flow rate is stepped up, the bed expands to a new height for each flow rate, the particle concentration becoming correspondingly less, ultimately tending to infinite dilution and transport. If at any stage the flow rate is suddenly stopped, the suspension settles at much the same linear velocity as that of the liquid before the flow was stopped. This is in accord with the concept of fluidization in liquids as sedimentation in reverse.[5] The expansion is reported as occurring smoothly, the particles as oscillating, and the phenomenon has been termed "particulate" fluidization.

When, however, the activating fluid is a gas, only a limited degree of smooth expansion is reported,[6, 7] occurring just before incipient fluidization. Thereafter, increased flow of gas passes up through the bed as bubbles, and the bed takes on the appearance of a boiling liquid. Particles are thrown up by bubbles bursting at the bed surface and the action gets more and more violent as the flow rate is stepped up until the bed is transformed into swirling clusters of particles filling the fluidization vessel and ultimately being transported in the gas stream. This type of behaviour has been termed "aggregative" or "bubbling" fluidization.

No satisfactory explanation of this strikingly apparent difference in fluidization behaviour has been given. The Froude ratio has been proposed[8] as a defining criterion, and extreme cases have been reported where aggregative fluidization has been noted in liquids, e.g., lead shot in water,[9] while particulate fluidization has been reported in air using hollow paper cubes.[10] A search of the extensive literature in this field reveals that by far the greater part of investigational effort in the past has been expended in macroscopic measurements and the formulating of correlating equations.[11] Such work has a more immediate application in industrial design but gives only limited help in discerning the functioning mechanism. More recently, however, increased attention has been paid to particular features within beds such as local density changes and the velocities of individual bubbles in gas-activated beds.[12, 13, 14, 15]

The present investigation has been concerned with the comparison of fluidization behaviour in both air- and in water-activated beds. The materials used were fused alumina catalyst, sand, silica, chalk and glass ballotini in sizes ranging from 2 mm to 40 μ diameter, and, in two cases, sub-sieve size. The materials were graded by sieving—an inefficient method, but satisfactory for general purposes. In some instances, a further sizing was effected by elutriation.

Non-uniform Expansion in Water-activated Beds

Much time was spent in attempting to obtain the expected smooth expansion of particle beds in water. However, in not one single instance was it found possible to expand from

a fixed bed to a disperse suspension without passing through a phase of non-homogeneous behaviour, which persisted under steady-state conditions. In some cases an apparently smooth expansion was observed, but closer investigation disclosed non-homogeneity. All these experiments were made in 2-in. diameter glass tubes using as bed support different types of cloth, wire gauze, perforated plates, beds of larger particles and porous membranes. The work of GROHSE[16] had shown the effect of the geometry of the bed support and it was accepted that lack of smooth expansion might be due to uneven water distribution. In one apparatus, therefore, use of a supporting membrane was obviated by employing a central downtake as water inlet, which also served as stirrer shaft tube for a stirrer blade at the bottom of the fluidization tube. It was hoped thereby to maintain a uniform slurry with incoming water in the lowest region of the bed and eliminate potential channelling, but disturbances persisted.

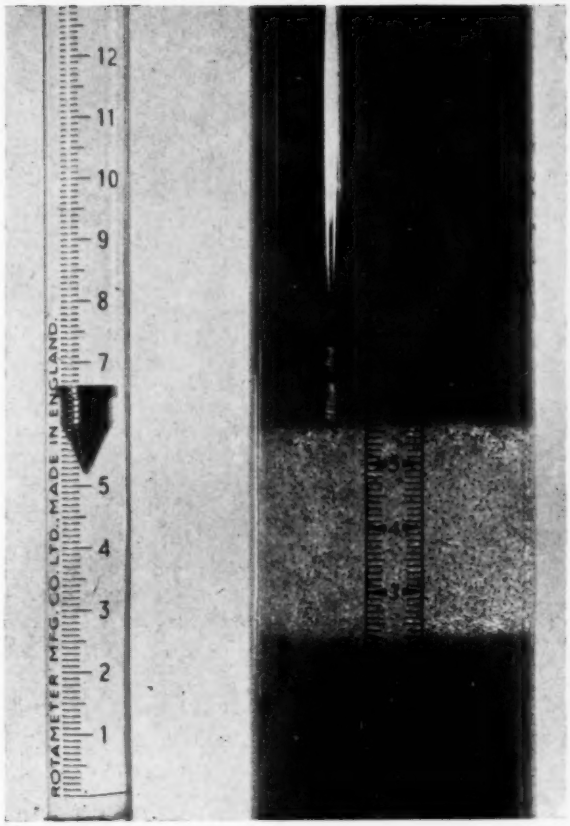
These findings led to the conclusion that the constitution of the bed itself contributes largely to uneven flow patterns. A bed of uniform particles evenly arranged would be an unlikely occurrence, and in the general case a particle bed resting on a porous membrane would comprise a multitude of potential flowpaths covering a complete range of resistances to flow. Fluid passing upwards through the bed would move at different velocities in different paths of the bed, and as flow rate is stepped up, a critical flow velocity inducing particle movement would be reached first in the region or channel of least resistance, provided that the bed did not rise as a solid plug first. Thus, initiation of bed dispersion from a limited number of centres seemed a logical deduction and fitted experimental observation.

The Experimental Programme

While it may well be that a uniform bed of identical regular-shaped particles subjected to a uniform flow of fluid would respond in a certain predictable manner, this is a hypothetical case that would never arise in industrial application, if indeed ever.

The work was therefore directed to a study of non-uniformities in fluidized beds and, in particular, channelling phenomena. Parallel studies were continued in air and water, and a simple probe technique was devised to explore the consistency of particle beds and particle movements within the beds. Particle movements and migration were also studied by using particles of different sizes, dyed in different colours. As the work progressed, evidence accumulated to indicate that, contrary to being anomalous behaviour, channelling would seem to be an integral part of fluidization behaviour, persisting in a modified form right up to transportation in both liquid and gas fluidized beds.

The experimental work described in this series indicates that the term "fluidized bed" as applied in general is technically incorrect, and could well be replaced by the term "activated bed". The analogy between an activated bed of particles and a fluid is a crude one indeed. Activated beds of particles are far from homogeneous, even when seemingly smooth and fluid-like. The experiments described in this series give evidence of a graded consistency in such beds, ranging from fully labile and fluid-like at the surface to fixed bed some distance below, with the amount of fixed bed diminishing as the fluid rate is increased. This occurs locally at one or more points in a bed, so that channels of labile particles are ultimately formed extending from the top down to the bottom of the bed. The model of a bubbling fluidized bed as suggested by this investigation is a dense bed of particles with labile channel regions up which slugs of particles are carried by fast-rising fluid. The bed as a whole is subsiding and migrating into the lower parts of the channels. The fluid trapped between the slugs constitutes "bubbles". Normally bubbles will follow in line, but in an actively bubbling bed, channels may migrate, may close and new channels may form. The bed and slug movement constitutes a solids circulation and the relative motion of particles and fluid at any part of the bed is governed by the same laws that govern sedimentation behaviour.



▲ **6** *Rise of artificial parvoids. Mixed black and colourless glass ballotini* 300-400 μ *held between two diaphragms* 50 *cm apart in a vertical tube* 5 *cm diameter. Superficial water velocity* 0.403 *cm/sec. Parvoid density is a measure of the rate of fall of particles from the roof of the parvoid.*

This model appears to be far different from that suggested by other investigators, where bubbles in particulate beds are considered as analogous to gas bubbles in liquids, but some similarity could be envisaged by modifying the model to bubbles rising in fluid channels, distributed in a dense bed.

The validity of the model is supported by observations made on an air-activated bed of wheat in a 6-in. diameter glass column with an inverted cone air inlet, the air entering by a 1-in. diameter orifice. A spouted bed would normally be formed with a single channel at the axis of the tube, with the bed circulation following the expected pattern. If, however, a thin, flat stick about 1 in. wide was inserted at an angle and rotated around its own axis, prior to fluidization, as the back air pressure built up, a channel could be induced to form from the inlet to the top of the bed at the wall, and spouting would follow that path, without tendency of the channel to become vertical. The channel could be induced to spiral and the spout to migrate slowly around the periphery of the bed. This persistence of bed form and identity of the channel was considered to be of some significance in the light of experiments with water-activated beds of chalk and of alumina, where a single spout could be induced and seen to wander around the periphery of a central downtake.

The "Activated Bed" Concept

In this series the term "activated bed" will apply to a bed of particles through which a fluid is flowing upwards at a rate such that one or more particles in the bed is kept in motion by the drag force exerted by the fluid. In the limit, the whole bed would be at rest save for a single particle either at the surface or trapped in a cavity and maintained in rotation, oscillation or other motion by the fluid flow. Each of these cases can be observed visually.

Parallel experiments with gas- and liquid-activated beds indicated that the difference in behaviour is one of degree or range rather than of kind. Fizzling followed by an apparent bubbling fluidization in liquids was almost invariably noted as a preliminary stage to disperse fluidization, and true mushroom-shaped bubbles have been demonstrated in beds of 2-mm. glass spheres fluidized in water. In the case of glass spheres of 100 μ diameter, mushroom-shaped low-density regions of bubble nature (parvoids) can been seen rising in channels. Here three phases can clearly be distinguished: a bulk dense phase, perhaps not fluidized, a fluidized dense phase and a lighter parvoid phase, all within a bed which viewed externally exhibits the features of smooth or particulate fluidization.

Of particular interest was the generation of low-density strata in water-activated beds of glass spheres as observed in parallel glass plate fluidization apparatus. These were formed at the bed support and propagated in succession to the top of the bed where they evanesced. Usually, the strata broke down into flat mushroom-shaped regions which moved upwards at much the same linear velocity as the strata.

These non-homogeneities in liquid-activated beds persist until a true disperse suspension is formed, but thereafter there is a wide fluid velocity range where true particulate, and relatively homogeneous, fluidization exists. Compared with this range, that of non-uniform expansion is relatively small, and much of this is not readily observed and appears to be uniform. On the other hand, in gas-activated beds, the non-uniform (bubbling) behaviour persists over a wide fluid velocity range, and particulate fluidization is normally only evidenced shortly before transportation.

In none of these experiments was a particulate fluidization obtained in gas or liquid, where the particles were held as a suspension without oscillation or circulation of the particles. This was at one time considered to be due to thermal currents or uneven fluid velocity distribution across the fluidization tubes. It is now believed, however, that particle movement is a necessary feature of particulate fluidization.

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Ignition and Growth of Fire

THE proposal to attack large fires in buildings with inert gas generators of high output has focused attention on the sparsity of information on the degree of reduced oxygen concentration required to suppress smouldering. Accordingly, it is reported in *Fire Research 1960*, that the Fire Research Station has been carrying out some studies of the ignition and smouldering of solids in atmospheres containing different concentrations of oxygen. It has been found that, for cellulosic materials, there is a minimum temperature for ignition of a given size of specimen; as the concentration of oxygen is reduced, this minimum temperature increases. In finely divided solids, it seems, there is a limiting concentration of oxygen below which smouldering will not propagate—this limit being estimated at about 8 per cent for cork dust and 12 per cent for sawdust.

In studies of the growth of fire, experimental results have been formed to confirm the theoretical relation for the size of flames emitted from windows:

$$\frac{L}{D} = F\left(\frac{R^2}{g\rho^2 D^5}\right)$$

where L is the flame height, R is the rate of production of gaseous fuel, ρ is the density of the fuel gas at ambient temperature, and D the length characteristic of the size of the fuel source. This relation can be used for predicting full-scale results from model tests.

However, R depends primarily on the heat transfer to the fuel, and in some small-scale studies R may itself depend upon L. In such cases the value of R for small models of full-scale fires would have to be adjusted—one method would be to have a relatively greater surface of wood exposed in small models than in proportion to D^2.

A few results of experiments now under way on the effect of wind on the spread of flame have shown that increasing wind speed appears to decrease the length of flame, presumably because the rate of entrainment of air into the fuel stream is increased, and the flame surface necessary for combustion is reduced.

Concerning fires in compartments with low ventilation, although the air flow is a main factor in controlling the rate of burning, variations in the fire load and its distribution may have an important effect. This has been shown by burning tests on fibre insulating-board panels in a compartment. The rate of burning increased as both the thickness t of the panel and the number N of panels increased. For a given fire load (proportional to the product Nt), the rate of burning did not vary significantly with the fuel surface area—a fact which is unexpected, unexplained, and is believed to be peculiar to the range of experimental conditions.

A large number of variables are involved in complete studies of small-scale experimental fires in compartments —the shape and size of the compartment, area of window opening, amount and nature of fuel, dispersion of fuel, dimension of fuel, wind orientation and velocity, and thermal properties of the enclosure. For this reason, the Conseil International du Batiment Commission de Travail Feu has agreed that such investigations might be made a joint international study. Preliminary investigations have shown that some standardization of techniques between the various participating laboratories is necessary.

Model tests on the venting of fires in single-storey buildings have shown that if the fire on the floor of the compartment is likely to be large, the vent area necessary to prevent any spillage of hot gases to a neighbouring compartment may be unacceptably large. Smaller roof vents, although they may have only a limited value in delaying the spread of a large fire, would nevertheless assist the removal of hot gases and smoke and would thus facilitate fire-fighting.

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Modified Schmidt Number DIFFUSION IN METHANOL

It has been shown earlier by the authors, when discussing the role of viscosity in translating diffusion data for water to other solvents, that the liquid diffusion coefficients for water can be easily translated to other solvents, using the modified Schmidt group $\frac{\mu V_m}{D}$ and the surface tension concept. This work presents results for the application of this concept to the liquid diffusion coefficient in methanol. The equation presented for the diffusion in methanol can be used for all solutes having a liquid viscosity less than 1 cp within an average error of 10 per cent

by S. H. IBRAHIM and N. R. KULOOR

WE have shown earlier that surface tension plays an important role in translating the liquid diffusion coefficients in water to solvents like benzene and methanol.[2] For a gas to diffuse into the liquid a certain amount of extra work has to be done to break the barrier of extra work due to the surface. Once the gas breaks through this barrier, the diffusion coefficient defines exactly the work it has to do to penetrate into the liquid molecules in the interior of the liquid. This extra work to break the surface barrier is characteristic of the solvents. Taking water as the reference state, the ratio of surface tension of solvent to water represents the relative energy requirement. In the earlier work[2] this concept was tested for benzene. The same approach is employed and this concept is verified for methanol in this work (Fig. 1, Table I). Excellent agreement is found. However, even critical constants and viscosity data seem to be rare for certain organic liquids. If one datum was available the other one would be missing. Hence it was not possible to verify this concept for many cases. However, using WILKE'S[3] method for diffusion coefficients and ARNOLD'S[1] method for viscosities, we have tested our method for nearly 20 cases. As more and more experimental data are available for various systems the utility of this approach will be appreciated. As such, extensive diffusion data are available for three systems: viz., water, benzene and methanol.

It must be mentioned here that when the liquid viscosity of the solute goes beyond one centipoise the method fails to agree with the values of WILKE.[2] As long as the liquid viscosity of the solute remains within 1.00 cp, the new method agrees well within 10.0 per cent error, either with the experimental value or with the values calculated by WILKE'S[2] method. This is expected because we have chosen water as the reference state. If the viscosity of the solute goes beyond the viscosity of the reference state, our assumption of reference state can no longer hold good.

Symbols Used

D = diffusion coefficient, cm²/sec;
μ = viscosity poise (centipoise in WILKE'S equation);
M = molecular weight;
V_m = molecular volume;
T_c = critical temperature, °K;
T_r = reduced temperature, °K;
χ = association parameter;
$\theta = T_b/T_c$;
D_{exp} = experimental;
D_w = WILKE;
D_T = this work.

TABLE 1—Diffusion in Methanol
Temp. 20°C.

No.	Substance	M	N'_{Sc} (water)	$M \times \frac{\text{S.T. Water}}{\text{S.T. Methanol}}$	Remarks
1.	Acetylene	26	240	83.70	
2.	Methanol	32	315	103.00	
3.	Propylene	42	444	135.20	See Ref. 2
4.	Ethanol	46	503	148.10	
5.	Propanol	60	655	193.20	
6.	Acetic acid	60	676	193.20	
7.	Butanol	74	930	238.20	
		From the Equation $D \times 10^5$ cm²/sec			
		D_{exp}	D_T		
8.	Bromobenzene	1.75 E	1.90 T		
9.	Ethyl bromide	2.40 E	2.30 T		
10.	Carbon tetrachloride	1.70 E	1.91 T		
11.	Chloroform	2.10 E	2.50 T		
12.	Ethyl ether	3.42 W	3.20 T		
13.	Acetone	3.00 W	3.35 T		
14.	Carbon disulphide	3.15 W	2.75 T		
15.	Ethyl formate	2.75 W	2.70 T		
16.	Acetaldehyde	5.00 W	4.50 T		
17.	Ethyl acetate	2.25 W	2.50 T		

Procedure for Estimating Diffusion Coefficients

Diffusion Coefficient in Methanol:

Plot N'_{Sc} (diffusion in water) against (molecular weight) $\times \left(\frac{\text{surface tension of water}}{\text{surface tension of methanol}}\right)$ for known values of D_{exp} (water) or use the equation (for methanol only)

$$D = \frac{\mu V_m}{4M - 75}$$

Limitation: Liquid viscosity of the solute should not be more than 1 cp. Note the deviation of butanol and ethanol in the graph.

The following equations were employed where experimental values are not available

$$\mu^0 = \frac{0.00270\, M^{1/2}\, T_c^{1/2}}{V_m^{2/3}} \cdot \frac{T_r^{3/2}}{T_r + 1.470}$$

$$D_{12} = \frac{7.4 \times 10^{-8}\,(\chi M)^{1/2}\, T}{\mu V_m^{0.6}}$$

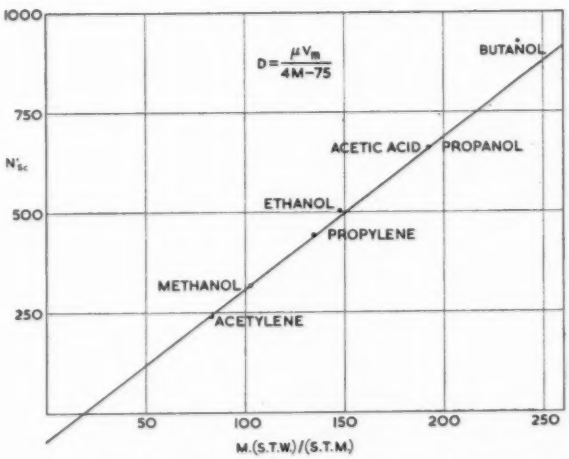

Fig. 1. Diffusion in methanol (liquid).

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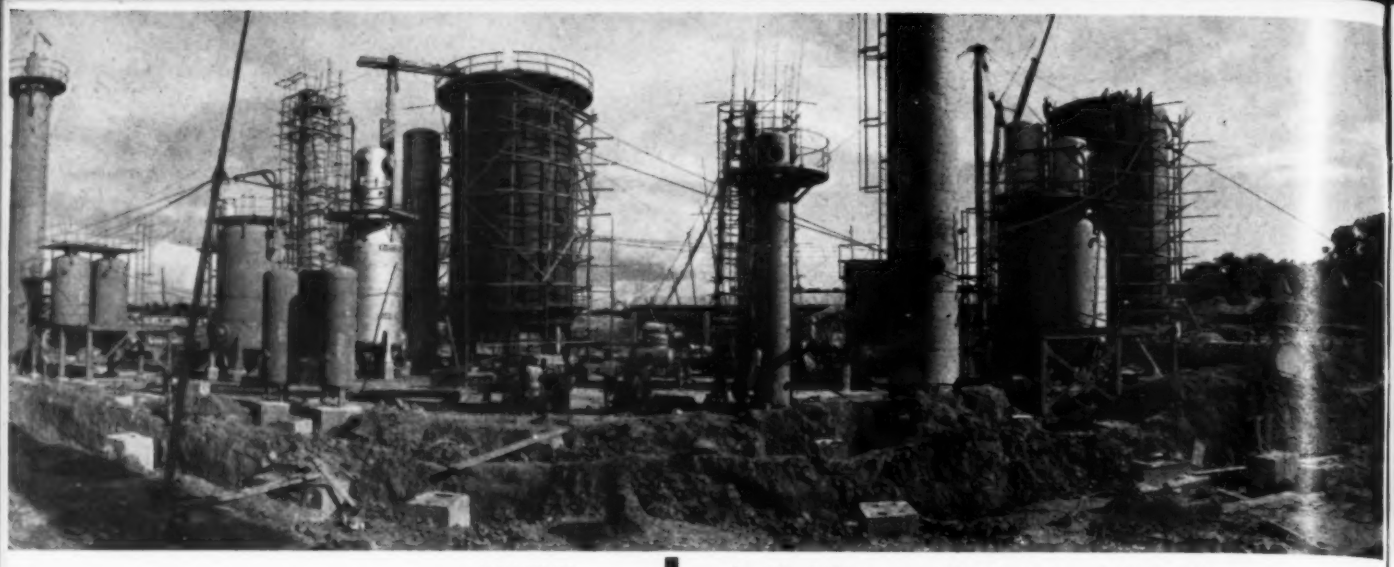

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▲ 1 *The Pakistan urea plant in course of construction by Kobe Steel Works Ltd.*

JAPAN'S CHEMICAL PLANT INDUSTRY

The rapid development of Japan's chemical industries has led to the expansion of Japan's chemical plant industry, both in volume and in the range of products. This development has been fostered by numerous licence agreements concluded with foreign firms. At present Japan is already exporting machinery and plant, an example being the construction of a fertilizer plant in Pakistan. The article describes the highly modern, largest and foremost integrated "plant maker" in the Far East. The growth of Japanese industries and their development programmes offer interesting possibilities to U.K. and other Western firms

by V. WOLPERT

ACCORDING to Japanese Government estimates, the investments in the country's chemical industries during the year 1 April, 1961, to 31 March, 1962, will amount to the equivalent of £227 million, including £110 million in the petrochemical industry and £29 million in the synthetic fibre industry. These investments in plant and machinery are indicative of the further rapid advance of Japanese chemical industries, with which the development and expansion of the Japanese chemical plant industry is closely connected. At the same time, this buoyant development creates additional possibilities for many Western firms in the Japanese market.

During the last few years (1955-1960) Japan's chemical industry achieved remarkable successes in the volume of output. The annual production of the chemical industry has now doubled, and Japan has become a major maker of chemical fertilizers, synthetic dyestuffs and fibres as well as sulphuric acid and soda, and many other chemicals. The 10-year plan of the Ikeda Government aims at doubling Japan's national income by 1970; it envisages the trebling of chemical output, and a virtually fourfold increase in petrochemicals by 1970.

Therefore, a rapid expansion of various branches of the machine-building industries is necessary, and the chemical plant industry, whose production reached £55.5 million in 1959 (more than double the 1955 production) is certain to expand rapidly. By the end of the war, the industry of Japan was technologically backward compared with that of Europe and the U.S.A., and in 1950 the Japanese Government promulgated the "Law Concerning Foreign Investment" which facilitated the entry of foreign capital and technologies. This law enabled Japanese firms to buy know-how from foreign firms, as this was considered to be the quickest way of catching up in the technological field. despite the fact that such agreements meant payment of royalties in foreign exchange at a time when Japan was deficient in foreign balances.

Introduction of Advanced Technologies

Compared with other Japanese industries, the chemical plant industry was particularly active in concluding agreements with foreign firms for the introduction of advanced technologies. Of the total number of about 1200 technological agreements concluded, it is estimated that about 25 per cent of them refer to chemical plant and processes. In a number of cases, in addition to supplying their technical know-how, foreign firms have participated financially in these Japanese enterprises.

Most of the technical arrangements were made with U.S. manufacturers, but Swiss, West German and French firms have been also active in this respect. Among the few British firms which had signed technical know-how agreements by the end of 1958 were The Power Gas Corp. with

Mitsubishi Chemical Machinery Co. for the manufacture of P.G.C. gas generators (1954); Humphreys & Glasgow with Ishii Iron Works Co. for gasification plant (1956); Millspaugh Ltd. with Japan Steel Works Ltd. for suction pick-up system for paper machines (1956); and R. H. Windsor Ltd. with Ikegai Iron Works Co. for plastics moulders (1958).

Research and Development

Japanese manufacturers have also been establishing their own research and development laboratories. An example is Hitachi Ltd., which employ at their Central Laboratory near Tokyo over 1000 persons, including about 300 university graduates. The rapid development of Japanese industries creates new possibilities for foreign firms to co-operate with Japanese interests. A recent issue of the monthly report published by T. F. M. Adams & Co. Ltd., Tokyo, a firm which specializes in bringing together interested Western and Japanese parties for the purpose of joint ventures, licensing and contract manufacturing activities, listed a number of agreements such as that of Pennsylvania Engineering Corp. (U.S.A.) with Kawasaki Dockyard Co. for the manufacture of oxygen-blown converters, mixers, etc.; of Stone & Webster Engineering Corp. (U.S.A.) with Nippon Petro-Chemical Co. on guidance in design, construction and operation of ethylene manufacturing equipment, and of IPA acetone manufacturing equipment. This American corporation has also concluded agreements of technical assistance with Mitsui Petrochemical Industries for the manufacture of ethylene-propylene from naphtha, with Mitsubishi Petrochemical Co. for guidance in basic design, construction and operation of ethylene plant, and with Sumitomo Chemical Industries for ethylene for use in polyethylene production. The Standard Vacuum Oil Co. (U.S.A.) has signed an agreement with Toa Nenryo Kogyo Co. on the building of steam cracking equipment and another agreement extending the license period of general petroleum refining. Among others may be mentioned Friedrich Uhde G.m.b.H., of West Germany, who concluded agreements with several Japanese firms for technical assistance in design, construction and operation of acetaldehyde plant; U.O.P. (U.S.A.) signed an agreement with Nippon Gasoline Co. on basic detailed design of fluid catalytic cracking equipment (for Nippon Oil Refining Co.). Among recent applications reported in *Japan Chemical Week* which have been submitted by Japanese interests were one by Ishihara Sangyo Co. for the introduction of the Tielen's technology from West Germany for new sulphuric acid plants, and another by Toyo Koatsu Co. which is interested in a liaison with Swiss Glin Hemie Co. for the manufacture of urea-foam.

Among recent agreements concluded by British firms were the I.C.I. agreement with Sumitomo Chemical Industries on polyethylene manufacture technology, and the Hector Whaling Ltd. agreement with Kyokuyo Hogei Co. relating to technical guidance and the operation of extracting equipment for whalers.

Western Co-operation

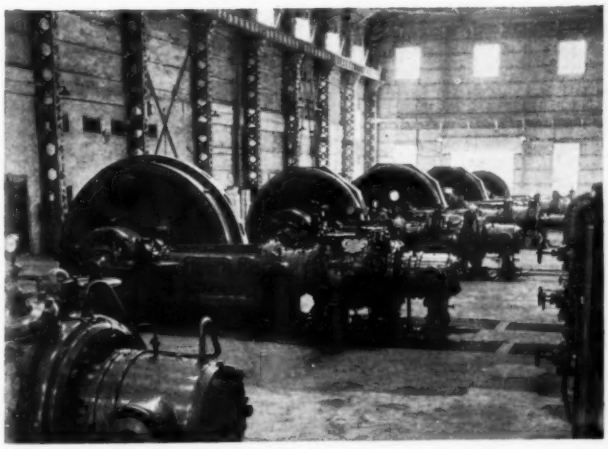
There is no doubt that co-operation with leading Western firms has contributed considerably to the development of the Japanese chemical industry and the chemical plant industry, but this has also proved valuable to the Western partners. In fact, some co-operation of this sort dates back to the pre-war period. The Japan Distillation Apparatus Manufacturing Co. Ltd. were established in 1937 with the technical co-operation of the French company Les Usines de Melle S.A., for the purpose of undertaking the engineering, fabrication and installation of plant and equipment in fermentation and distillation industries. The range of manufacturing activities has now broadened and this company, of which the French company is still a shareholder, is now the sole correspondent and the approved maker in Japan of the Société Technique D'Entreprises Chimiques (S.T.E.C.). It also represents the Kuhlmann concern, the parent company of S.T.E.C.

SUECO (Shibaura United Engineering Co. Ltd.) were established in March, 1939, as a joint enterprise between the United Engineering & Foundry Co., of the United States, and TOSHIBA; the company's present manufacturing programme includes rubber and plastics machinery.

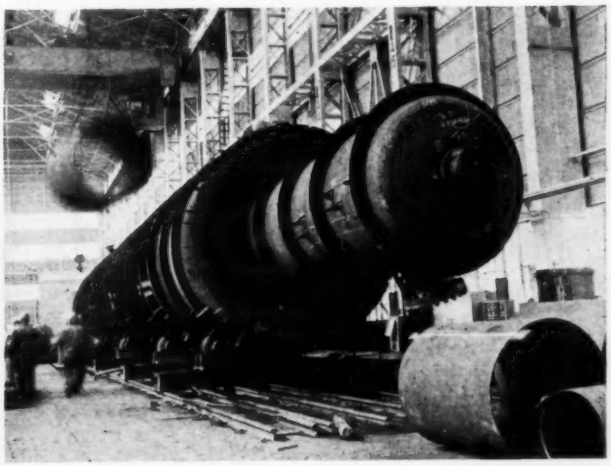
A post-war joint venture is the Niigata Worthington Co. Ltd., a company established in November, 1953, by joint investment of Niigata Engineering Co. Ltd., of Japan, and the Worthington Corp., of the U.S.A. In addition to acting as sole agent in Japan for all Worthington products, the company manufactures under licence various types of pumps, compressors and other machinery.

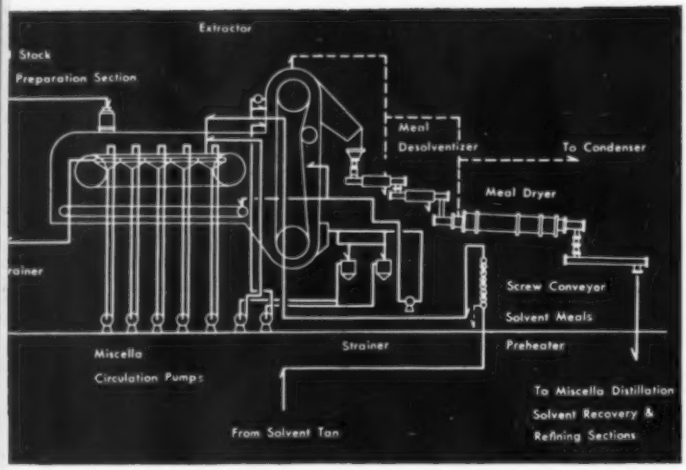
Another important joint venture is Shinko-Pfaudler Co. Ltd., established in 1954, which is an organization jointly owned by the Kobe Steel Works Ltd., of Japan, and The Pfaudler Co., of the U.S.A. (now a division of Pfaudler Permutit Inc.). Shinko-Pfaudler Ltd. makes Pfaudler equipment for the various chemical and processing industries,

2 *Ethylene compressors at Nohawa, manufactured by Sumitomo.*



3 *Distillation tower being fabricated at the Chiyoda Chemical Engineering & Construction Co. Ltd.*





4 *The L-type continuous extraction plant developed by Chiyoda.*

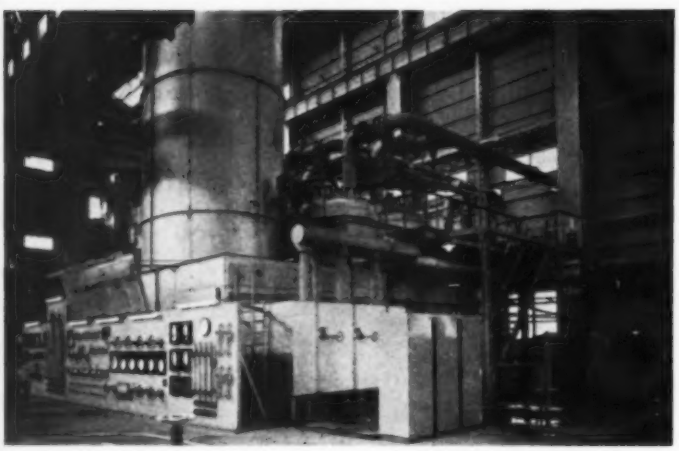
whereby the glass-lining materials are supplied by The Pfaudler Co. and free exchange of information is maintained with Pfaudler companies in other countries. As a result of the merger between Pfaudler and Permutit in 1957, the Shinko-Pfaudler Co. signed a technical agreement with Permutit for water conditioning and ion exchange equipment in 1959. The Shinko-Pfaudler works are equipped with a specially designed glass-lining furnace, probably the largest in Asia, which can fire reactors up to 30,000 l and storage tanks up to 50,000 l in capacity.

It is worth noting that Japan is now exporting complete chemical plant, as well as individual items of equipment.

An integrated Fabricating Plant

A company which typifies Japan's expansion as a constructor and designer of chemical equipment is the Chiyoda Chemical Engineering & Construction Co. Ltd. This company is a well-balanced unit, equipped with adequate fabricating machinery, as well as a large design, research and development staff. The company descends from the Construction Department of the Mitsubishi Oil Co. and was formed in 1948. At that time its capital was 1 million yen, and such has been the development that the investment is now 1200 million yen.

5 *Oxygen plant, 3000 in^3/h, at the Fuji Iron & Steel Co. Ltd., manufactured by Kobe Steel Works Ltd.*



Its principal manufacturing plant is at Kawasaki and the equipment installed includes a 1500 ton hydraulic press of 20 ft span built by the Kobe Steel Works; a preload, four-roll bending machine of 12 ft width, capable of handling plates of up to 3½ in. thick; a number of Tandem-type submerged-arc welding machines; an annealing furnace, being 16 ft × 16 ft × 76 ft; and two automatic flame planers.

The main bay of this factory exceeds 720 ft in length; the range of fabrication undertaken is wide—for example, distillation towers of up to 120 ft long, heat exchangers with tube plates for more than 8000 tubes per plate, Hortonspheres and floating roof tanks, in addition to jacketed kettles, autoclaves and open and closed mixing vessels.

The company has built a number of plants for which the basic information has been supplied by foreign companies, the detailed design in many cases being carried out by the Chiyoda staff. These plants include a styrene monomer plant (design data supplied by the Bataafsche Petroleum Co.), ethylene oxide unit, ethylene glycol unit, perchloroethylene plant (Scientific Design Co. of America), continuous rayon fibre plant (Rayon Consultants Inc.), platforming unit, unifining unit, Udex unit, feed preparation unit (Universal Oil Products Co.), and a uranium refining pilot plant (Weinrich & Associates).

Continuous Solvent Extraction Plant

Among the designs evolved exclusively by Chiyoda is a continuous solvent extraction plant for treating soya beans, rice bran and for extracting oil from linseed, copra, cottonseed and so on. A plant of this type was recently installed at Okinawa, its main advantages over batch plant being the high concentration of miscella, low solvent loss, ease of installation and operation, and low operating costs.

Consulting Institute

An institute with important consulting functions, The Japanese Consulting Institute, was formed in September, 1955, with the support of the leading equipment makers. This body will undertake preliminary surveys of projects, evaluate them, and, when the manufacturing unit is required, will carry out detailed designs, estimate costs and prepare tender and contract documents. It will also recommend suitable contractors and fabricators and will look after the commissioning and proving of completed plants. Some of the plants in which this Institute has played the major role include fertilizer plants in East Pakistan, Peru and Brazil, and it seems certain that the Institute is destined to play an even more important part in the export of complete plants.

So far as the East Pakistan plant is concerned, this will be completed before the end of the year and has a designed output of 110,000 tons of urea and 250,000 tons of ammonium sulphate. The main contractor is the Kobe Steel Works with Mitsubishi Heavy Industries (Reorganized), Ishikawajima Heavy Industries, Fuji Electric Manufacturing Co. and the Meidensha Co. all having their appropriate share of the equipment.

In its entirety the equipment for the East Pakistan plant is of Japanese manufacture, an interesting item being the synthesis gas compressor supplied by the Kobe Steel Works. The natural gas reforming equipment was supplied by Mitsubishi Heavy Industries (Reorganized) as well as the plant for CO_2 removal. Storage facilities for liquefied ammonia and the urea reaction equipment were supplied by Ishikawajima-Harima Heavy Industries.

The design was undertaken by the Japan Gas-Chemical Co. and the Sumitomo Chemical Industries Co., with the Consulting Institute and the Chemical Construction Co. of U.S.A. acting in concert as consultants.

The Process Stream Analyser — To a User

THE Mobil Oil Co. Ltd. have recently installed process stream analysers at their Coryton refinery and, in a paper on this subject,* information is provided which should be useful to anyone contemplating similar installations.

What They Are

Process stream analysers will continuously, or repetitively, measure a physical or chemical property of a gas, liquid or solid process material on any plant, but their greatest long-term future is probably in fully-integrated control systems which incorporate computational techniques. Measurement is carried out in a variety of ways and the instruments can be classified into two main classes:

(1) Analysers which automatically simulate manual tests, i.e., robots. Such instruments are generally cyclic in operation and produce results which are directly comparable with laboratory tests. Examples are the Reid vapour pressure analyser, the end-point analyser and the boiling-point analyser.

(2) Analysers which measure or detect some parameter which may directly determine or inferentially reflect the process stream property or condition. A continuous analyser which gives a direct determination of a parameter is the paramagnetic oxygen analyser (with reservations), while the thermal conductivity and infra-red analysers give a more inferential result. The gas-liquid chromatograph is an example of a cyclically operating instrument which gives a precise analysis of the physical composition of a material.

Advantages

The savings which can result from an analyser installation may generally fall into the following six categories:

(1) *Safety* to life and property usually offers a significant financial incentive.

(2) *Labour-saving* on highly instrumented, continuous processes will not be significant since staffing is generally at a minimum compatible with safe operation under emergency conditions. Where analysers are used for blending purposes, in storage tank farms, distribution depots, etc., a saving in labour can be made, especially where they are used in conjunction with remote control.

(3) *Reduction in initial plant costs* by the use of analysers is not yet possible. Reductions in design safety factors may be possible if the analyser will ensure operation within a narrow specification. However, this is considered improbable in practice, since the margin built into the average new plant is quickly reduced, as the throughput is increased beyond the original design value, to a point just short of where quality begins to suffer. This is when the analyser is essential to maintain product specification with the maximum throughput. A more realistic saving in plant costs is the possible reduction of intermediate storage capacity.

(4) *Quality and uniformity*. Here a suitable analyser will reduce the "quality give-away".

(5) *Reduction in the running costs* of a plant is the most common reason for installing analysers.

Net Payout and Costs

An attractive payout can often be worked out for an analyser installation, but the gross cost is often underestimated. On-stream time for the analyser will seldom be 100 per cent, and allowance should be made for all the factors which will affect it. In estimating a realistic gross cost it is misleading to consider only the instrument's f.o.b. price, plus a nominal figure for electrical and piping costs.

The nature of the process material at the point of analysis and its preservation as a representative sample must be considered when estimating capital cost. Costly jacketed or heated lines, cooling and drying facilities, adequate filtering, weatherproofing, built-in calibration and test facilities, and adequate spares must be anticipated in many cases. An important item is the commissioning and early trouble-shooting cost which may be excessive if major modifications to the original installation are found necessary.

Running costs will include the price of utilities, carrier gas and purging nitrogen, as well as process material loss incurred if the process stream to the analyser is diverted to atmosphere.

Additional costs are incurred when analyser readings must be correlated with laboratory results.

Finally, an organisation which develops its instrumentation to include process stream analysis and computational aids, cannot continue with the original instrument maintenance force.

The foregoing indicates that the true overall cost of an effective installation may be very high, yet an excellent payout is still possible. Few analyser applications within a particular industry are unique, and an installation can usually be repeated elsewhere. In this way the high initial costs on the first installation can be justified as the means of economizing on other similar installations which can be made more profitable.

Selection and Application

The selection and application of process stream analysers is best carried out by a team composed of a chemist, a process engineer and an instrument engineer. Thus all factors will be better assessed in their proper perspective.

Although direct measurement of a property is normally preferred to an inferential method, sometimes no direct method may be available or a reliable inferential measurement may be adequate. Also, a high accuracy should not be specified is not essential, when an instrument which will accurately repeat results is available at an economic price.

Installation, Location and Housing

Some maintain that a special building is needed to house all analysers associated with a plant, despite the fact that sample lines must be considerably extended. Justification for this is better protection and easier maintenance.

Another view is that analysers should be sufficiently rugged to be mounted on the line or vessel concerned. At Coryton instruments are close-coupled and plant-mounted wherever possible.

Installation costs are less during the plant construction stage. When analysers are introduced after construction difficulties arise due to lack of space for housing the panel-mounted equipment. However, the plant construction stage is in some ways an unsuitable time for the installation of analysers as the work may not receive the detailed attention it requires.

Maintenance

Maintenance is probably the most difficult single item in a programme of analyser installation. The sampling system of an analyser can be the weakest link, and, once installed, there is little that can be done with a troublesome arrangement, other than to regularly blow down lines, replace filters, etc. Minor modifications can often result in improvements and if the routine maintenance is too frequent it will usually pay to re-plan the entire system.

* L. W. Farey and W. E. Lacey, "The Process Stream Analyser—To a User".

66.023.2: 621.642.01

THE GRAPHICAL CALCULATION OF CARBON AND LOW ALLOY STEEL FUSION-WELDED PRESSURE VESSEL SCANTLINGS

by J. L. RYDER

Section 3—10% Knuckle Radius End Pressings (Concave to Pressure)

This is the third of a series of four graphs to facilitate the approximation of pressure vessel scantlings to B.S. 1500: 1958. The first and second graphs dealt with shells and 6 per cent knuckle radius end pressings respectively. In a future edition of BRITISH CHEMICAL ENGINEERING the final graph of the series will be published determining the pressure-diameter-thickness relationship of 2:1 semi-ellipsoidal profile dished and flanged ends.

This graph is drawn especially for dished and flanged ends where the inside diameter, *Di*, is equal to the inside spherical radius, *Ri*, and the inside knuckle radius, *ri*, is 10 per cent of the inside diameter. It enables the thickness (max. $1\frac{1}{2}$ in.) of end pressings up to 120 in. diameter and 500 psi design pressure to be obtained easily. Conversely, it will show the permissible design pressure of an existing dished and flanged end of appropriate profile, provided diameter and thickness are known.

The curves are drawn to the equation,

$$t = \frac{p \cdot Do \cdot K_1 \cdot K_2}{2 \cdot f \cdot J \cdot K_3}$$

taken from B.S. 1500: 1958, Section Three F, equation 15.

Four necessary conditions are imposed on the curves and these are:

(1) No allowance is made for corrosion or for thinning which takes place during forming. In effect, this means that to whatever thickness is determined from the graph should be added an allowance equivalent to the corrosion expected during the life of the vessel; also an additional amount to compensate for any thinning which may take place while

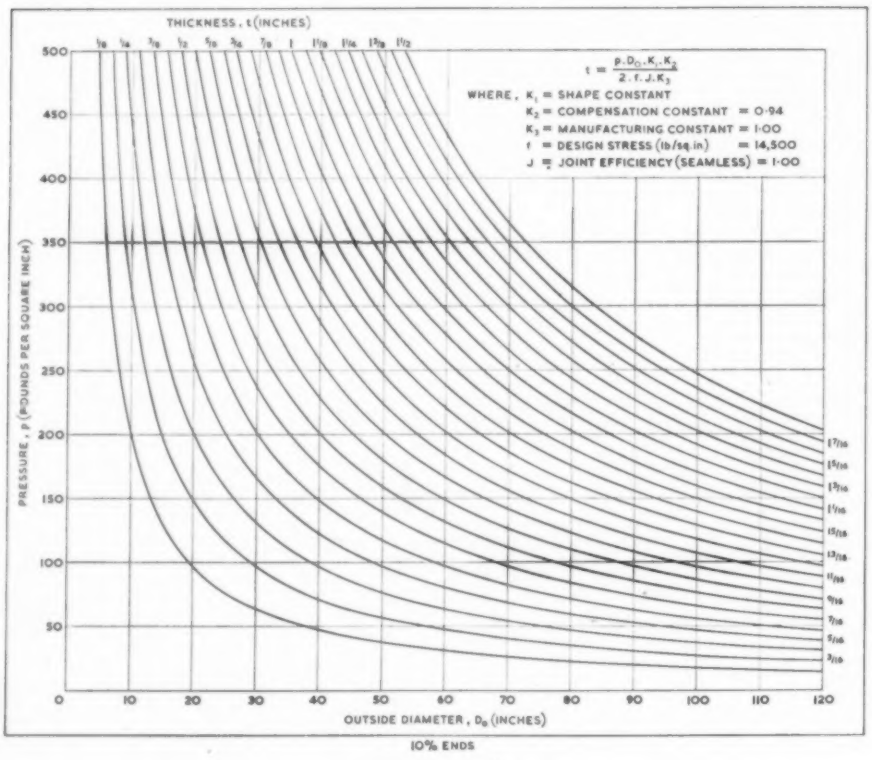


*Chart for determining wall thickness of low alloy and carbon steel pressure vessel ends to B.S.*1500: 1958

the plate is being formed to dished and flanged profile.

(2) The material design stress is 14,500 psi; i.e., the design metal temperature does not exceed 650°F for normal boiler flanging or welding quality mild steel plate.

(3) The end is made from a single plate without a weld seam ($J = 1.00$).

(4) Any openings in the end will be fully reinforced ($K_2 = 0.94$) and the method of manufacture shall be forming by spinning or pressing in full or ring dies ($K_3 = 1.00$).

Example

Determine the normal working pressure permissible (assuming a 10 per cent increment for safety valve setting) for a dished and flanged end pressing which has the following profile.

Outside diameter	52 in.
Inside spherical radius	51 in.
Inside knuckle radius	$5\frac{1}{4}$ in.
Thickness	$\frac{1}{2}$ in.

Allowance is to be made for corrosion of $\frac{1}{16}$ in. expected in service.

Thickness available for stress $= (\frac{1}{2} - \frac{1}{16}) = \frac{7}{16}$ in.

Enter the graph at the point $Do = 52$, proceed vertically to the line $t = \frac{7}{16}$ in. and read off the corresponding design pressure of 133 psig horizontally to the left.

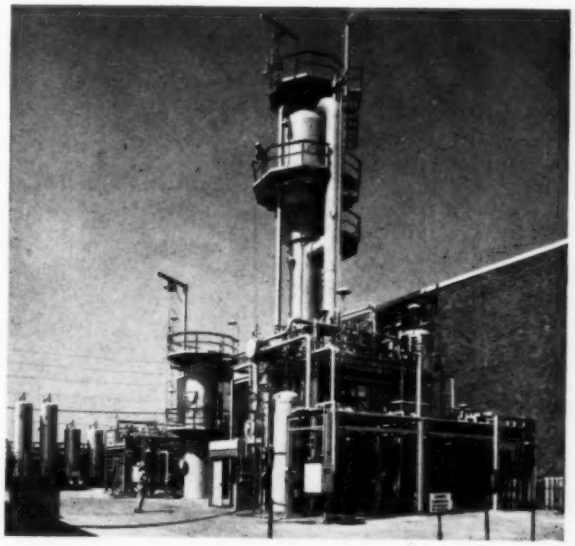
$$\text{The normal working pressure} = 133 \times \frac{10}{11} = 120.9.$$

(say) 120 psi.

Should a design occur where either the stress is different from that stated (i.e., 14,500 psi), or it is necessary to have a welded seam in the end pressing, due allowance can be made by applying an appropriate factor in a similar manner to that given in the article accompanying the graph for shells (see *British Chemical Engineering*, **6**, 192).

The above information, extracted from B.S. 1500: 1958, *Fusion Welded Pressure Vessels for use in the Chemical, Petroleum and Allied Industries*, is reproduced by permission of the British Standards Institution, 2 Park Street London, W.1, from whom official copies of the complete standard may be obtained, price 40s.

Fractionation Research Incorporated



FRI IS a co-operative non-profit organization established for the purpose of developing the ultimate in fractionating equipment and processes. Fifty-eight oil and chemical engineering companies are participating in the most co-operative research programme on fractionating equipment ever attempted. Each company receives copies of all reports, and a royalty-free licence to use any device or process developed. No company is required to disclose any of its "know-how" and no licence flows from any company to FRI.

The contribution of each company is graduated according to the size of the contributor and the maximum contribution is $10,000 per year—less than half the cost of equipping, maintaining and remunerating a research engineer in the U.S.

Already FRI has achieved breakthroughs in design technology which have resulted in savings to its contributors of hundreds of thousands of dollars. These results more than justify the cost of participating in FRI, and an invitation to do so is extended to all interested companies.

The actual research work of this effort is carried out by a staff of four chemical engineers under the direction of the technical director. They prepare reports and keep the fractionation tray design handbook constantly up to date by incorporating the new data as they are evaluated.

In addition, FRI has under retainer two technical consultants who advise and consult with the technical advisory committee, the technical committee and the technical director.

Research and Development Programme

This is being conducted in three ways. The principal effort is carried out in a commercial-size distillation unit. The programme also employs small- and industrial-scale simulators which are leased. The third phase consists of tests on commercial columns of FRI member companies.

In the commercial-size distillation unit, over 80 separate trays of various types and designs have been tested. Each type has been found to have its advantages and disadvantages, but most important is the realization that there is no best tray for all applications.

To make optimum use of the experimental distillation unit, trays undergo preliminary tests in a simulator. Only those trays which show promise over the known trays are investigated in the distillation unit.

The acid test of most of what FRI develops in the experimental distillation unit is to compare the performance of tray designs in commercial columns with that observed in the experimental unit. This is done through the plant test programme in which member companies participate. The tests are used by all members to extend the experimental data to other systems and to refine the design procedures.

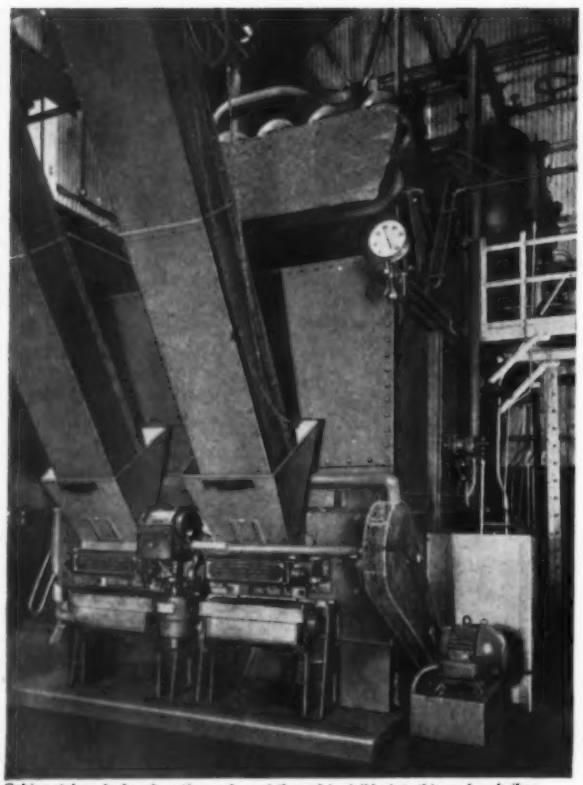
The experimental distillation unit has two sections: one is 4 ft dia., the other is 8 ft dia. The 4-ft section can test ten trays on 2-ft spacing; the 8-ft section can test six trays on 2-ft spacing (see illustration).

The technical staff also spends a lot of time developing correlations and design procedures from the tests of commercial columns. These procedures are distributed to member companies for inclusion in the "fractionation tray design handbook", now considered the finest collection of design procedures for fractionating devices in the world.

Fractionation Research Incorporated, P.O. Box 1389, Bartlesville, Oklahoma, U.S.A.

BCE 708 for further information

COAL—properly used—is the cheapest fuel for the Chemical Industry



Coking stokers feed coal continuously, quietly and invisibly into this modern boiler.

Search the industrial scene—and it is difficult to find any major industry that does not use chemicals. But even in the prospering chemical and chemical processing world, sound economics are of primary importance and wise managements will always make every possible saving and every possible improvement that will help keep prices stable while satisfying—and expanding—their home and overseas markets.

BEGIN AT THE BEGINNING—THE BOILERHOUSE

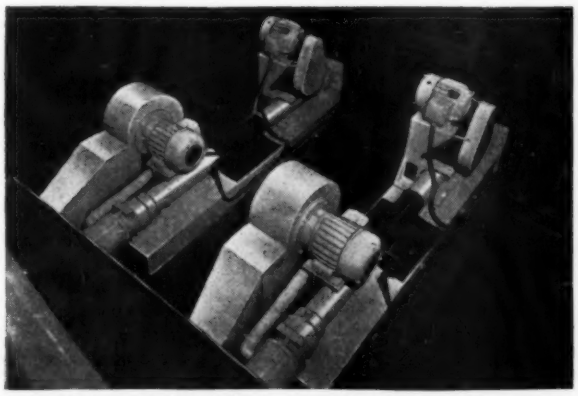
There are still some chemical plants that handicap their finances with outdated boilerhouses. To modernise other machinery while 'making-do' with inefficient boilers is to throw good money down the drain. Modern coal-burning installations can be so efficient that they will more than pay for themselves in a remarkably short time. They are, without question, the *first* essential in a chemical plant that is going to make rising profits for its management.

COAL IS THE RELIABLE FUEL

One question for any long-term planning is obvious: can supplies of coal be guaranteed? The answer is yes—without qualification. The mining industry—Britain's *largest single industry* is becoming increasingly efficient; its equipment is the best of its kind. And British coalfields contain enough coal to supply every industrial demand for centuries to come.

COAL IS CLEANER, HOTTER

Modern grading and washing methods ensure that coal is the most efficient and consistent fuel for every type of boiler—the ideal fuel for every section of the chemical and chemical processing industry. But to obtain the maximum heat at the lowest cost, coal should be mechanically stoked. A mechanical stoker automatically feeds the right amount of coal for the boiler load even when the load is varying; it burns coal at optimum efficiency all the time without the emission of smoke; and it virtually replaces the human element in boiler operation. There are many types of mechanical stokers, of which the most commonly used are the Chain Grate stoker, the Coking stoker, the Underfeed stoker and the Sprinkler stoker. Standard models are available for all sizes of boiler.



Two underfeed stokers feeding coal direct from a storage hopper into a modern vertical boiler.

OVER 80% OF BRITISH INDUSTRY USES COAL

The National Coal Board is determined that COAL shall continue to be plentiful, shall continue to keep our industrial power both dominant and progressive. You can depend upon COAL; its sources and supply are in our *own* hands, free from the fluctuations of foreign policies. Endless research by scientists and chemists working in the laboratories of the N.C.B. will ensure that coal will be increasingly profitable for its users.

DELIVERY—ON THE DOT —ON THE SPOT

The delivery of coal is today highly organised and completely reliable. Leading coal merchants have completely overhauled delivery and storage systems and are fully equipped to make sure that you get the right grade of coal when you want it and where you want it. And handling can be fully automatic. Furthermore, completely mechanised handling systems will transport coal from storage to furnace without any manual labour at all.

AND—WHEN YOU NEED IT— A NATION-WIDE FREE SERVICE

The vast resources of the National Coal Board are no further away than your telephone. At a flick of your finger, you can call upon one of the most comprehensive and efficient technical services in the world. No problem is too small or too big. You may want advice on coal quality, coal storage or coal-burning appliances or even on the siting of a new boilerhouse—whatever it is, a 'phone call or letter either to your coal supplier or to the Regional office of the National Coal Board will bring an authoritative answer to your problem.

FINANCE PLAN FOR INDUSTRY

No deposit, repayments spread over five years, low interest charges that can be set against Tax, full investment and other capital allowances, that can be claimed at once, these are the terms available to the manufacturer or businessman who wants to install modern coal-burning equipment without touching his capital resources.

Make use of the National Coal Board Industrial Finance Plan. The loans are made by Forward Trust Limited, who are members of the Midland Bank Group. A 'phone call or a letter to the Regional office of the National Coal Board will bring you full details.

SOLID FUEL—more heat at less cost—and it's British

PROGRESSIVE INDUSTRY IS GOING FORWARD ON COAL

ISSUED BY THE NATIONAL COAL BOARD

Abstracts

GROUP A — FLUID DYNAMICS

Flow of Entrapped Bubbles Through a Capillary

When liquids containing air bubbles flow through capillaries the resistance to flow is increased. This phenomenon has been studied in glass capillaries containing moving and stationary air bubbles which are large relative to the capillary diameter. Under these conditions the bubbles are essentially cylindrical in shape and are separated from the walls of the tube by a thin liquid film. This film thickness was found to be a function of bubble velocity and length, capillary diameter, liquid viscosity and interfacial tension. 11 refs., 5 diags., 5 charts, 3 tables.

R. H. MARCHESSAULT and S. G. MASON, *Ind. Eng. Chem.*, 1960, **52** (1), 79-84.

Hydraulic Conveying of Solids in Vertical Pipes

Data are presented for the vertical transport of several materials (sands, pebbles, zircon, manganese dioxide, perspex) at varied conditions of size distribution, slurry concentration, velocity and pipe dia. The results were satisfactorily correlated by the empirical equation:

$$\frac{i - i_w}{Ci_w} = 0.0037 \left(\frac{gD}{V^2}\right)^{\frac{1}{3}} \left(\frac{D}{d}\right) S^2$$

where i and i_w are the hydraulic gradients due to the slurry and water respectively; C is the delivered conc.; D is dia. of pipe; d is dia. of particle; V is mean velocity; S is ρ_s/ρ_w; ρ_s and ρ_w refer to the densities of the solid and water respectively. 1 diag., 16 charts, 2 tables.

D. M. NEWITT *et al.*, *Trans. Inst. Ch. E.*, 1961, **39** (2), 93-100.

Quantity and Behaviour of Liquid in Granular Solids

The author develops an equation for the distribution of the residual liquid in granular materials under the influence of mechanical forces, such as occur in centrifugation or filtration, and attempts to evaluate the various influencing factors as far as possible. He then analyses the progress of the process with the time during which capillary and film flow are determining. Finally, he indicates possibilities for determining residual moisture by model experiments. 7 refs., 5 diags., 11 charts.

W. BATEL, *Chemie Ing. Tech.*, 1961, **33** (8), 541-7.

Means for Visualizing Fluid Flow Patterns

This patent relates to an apparatus for determining both the absolute and relative velocities of a phosphorescent fluid flowing through a transparent conduit. The apparatus includes a source for exciting a narrow transverse band of the fluid to phosphorescence, detecting means such as a camera located downstream from the exciting source to record the shape of the phosphorescent band as it passes, and a timer to measure the time elapsed between operation of the exciting source and operation of the camera.

F. E. LYNCH, L. D. PALMER, H. F. POPPENDIEK and G. M. WINN, U.S. Pat. No. 2,984,744, issued May 16, 1961.

Hydraulic Resistances of Pipes when Steam-water Mixtures Flow Upwards at High Velocities and under Super-high Pressures

The experimentally established values of hydraulic resistances for steam-water mixtures were tabulated for wide ranges of parameters. The pipe bores under investigation were 6, 8, 10, 18 mm, the pressures 100, 140, 170, 200 ata, the mass velocity varied from 1000 to 4000 kg/m² sec, and the wetness factor from zero to unity. When the value of the wetness factor was reduced to about 0.25, the rate of increase of the hydraulic resistance of the pipes dropped sharply with any further reduction of the wetness factor. The heat-transfer coefficient also diminished at this point. This was explained by the change in the structure of the mixture and the flow properties. The minimum wetness at which this change of flow properties occurs is a function of the mass velocity and the pressure. The experimental procedure is described and an empirical fomula given from which the hydraulic resistances can be calculated. 2 refs.

M. M. PRZHIALKOVSKII and I. N. PETROVA, *Teploenergetika*, 1961 **§6**, 25-8.

The Flow of Gas in a Fluidized Bed at Low Pressure

The mechanism of the flow of gas in a fluidized bed at low pressure could be presumed from the analogy to the flow of gas in a capillary, but no such work had been reported. Experiments were carried out with sifted sand, silica gel and glass beads at 1 to 760 mm Hg pressure and 10 to 250 cm/sec linear gas velocity.

The results obtained may be summarized as follows: (1) Behaviour of a fluidized bed at low pressure resembled that at atmospheric pressure. (2) It is more difficult to have a uniform fluidized bed at low pressure than at atmospheric pressure. x, the ratio of pressure drop to the gravitational force of the bed, falls between 0.85 and 0.95. (3) The relation between the pressure drop and the flow velocity through the bed at low pressure can be correlated with modified friction factor, f'' (comprising function of void, Carman's shape factor, and the effect of slipflow), in the experimental region of the present work. (4) The minimum flow rate for fluidization is found to decrease proportionally with the decrease in operating pressure. However, at a pressure lower than 100 mm Hg or so, no such linear relationship is found. In this region a correction factor is proposed to determine the relation between the minimum flow rate for fluidization and the pressure. 9 refs., 2 diags., 9 charts.

S. KAWAMURA and Y. SUEZAWA, *Chem. Eng., Japan*, 1961, **25** (7), 524-9.

How to Calculate Pressure Drop in Spouted Beds*

This work was initiated to elucidate the pressure drop phenomenon occuring in the spouted bed. Using Leva's general theoretical equation for the flow of fluids through packed beds and experimental data on spouting bed pressure drops, two equations were developed that predicted spouting pressure losses. The pressure drop equations presented will make it possible to design pumps, fans or compressors that are required to move fluids through spouted beds. 4 figs., 1 flow diag., 3 charts.

L. A. MADONNA and R. F. LAMA, *Ind. Eng. Chem.*, 1960, **52** (2), 169-72.

Taylor Diffusion in Tubular Reactors

It is assumed that the model of Taylor diffusion can be used to estimate the effect of velocity profile and radial diffusion on conversion in tubular reactors in which chemical reaction and heat transfer take place. This leads to simple equations which become unstable when applied to an exothermic process, and a cell model is used to provide a numerical solution. 5 refs., 5 charts.

J. COSTE *et al.*, *Can. J. Ch. E.*, 1961, **39** (4), 149-51.

High-speed Photography in the Study of Two-phase Flow

The authors describe some possible applications of high-speed motion-picture photography in the study of two-phase, two-fluid flow. These include measurements of ripple or wave velocities in annular flow, and bubble velocities in bubble and slug flow. Motion pictures provide a better understanding of the interactions between the two phases. 9 refs., 6 figs., 1 diag., 3 charts.

R. A. S. BROWN and G. W. GOVIER, *Can. J. Ch. E.*, 1961, **39** (4), 159-64.

Applying Cascade Theory in Distillation

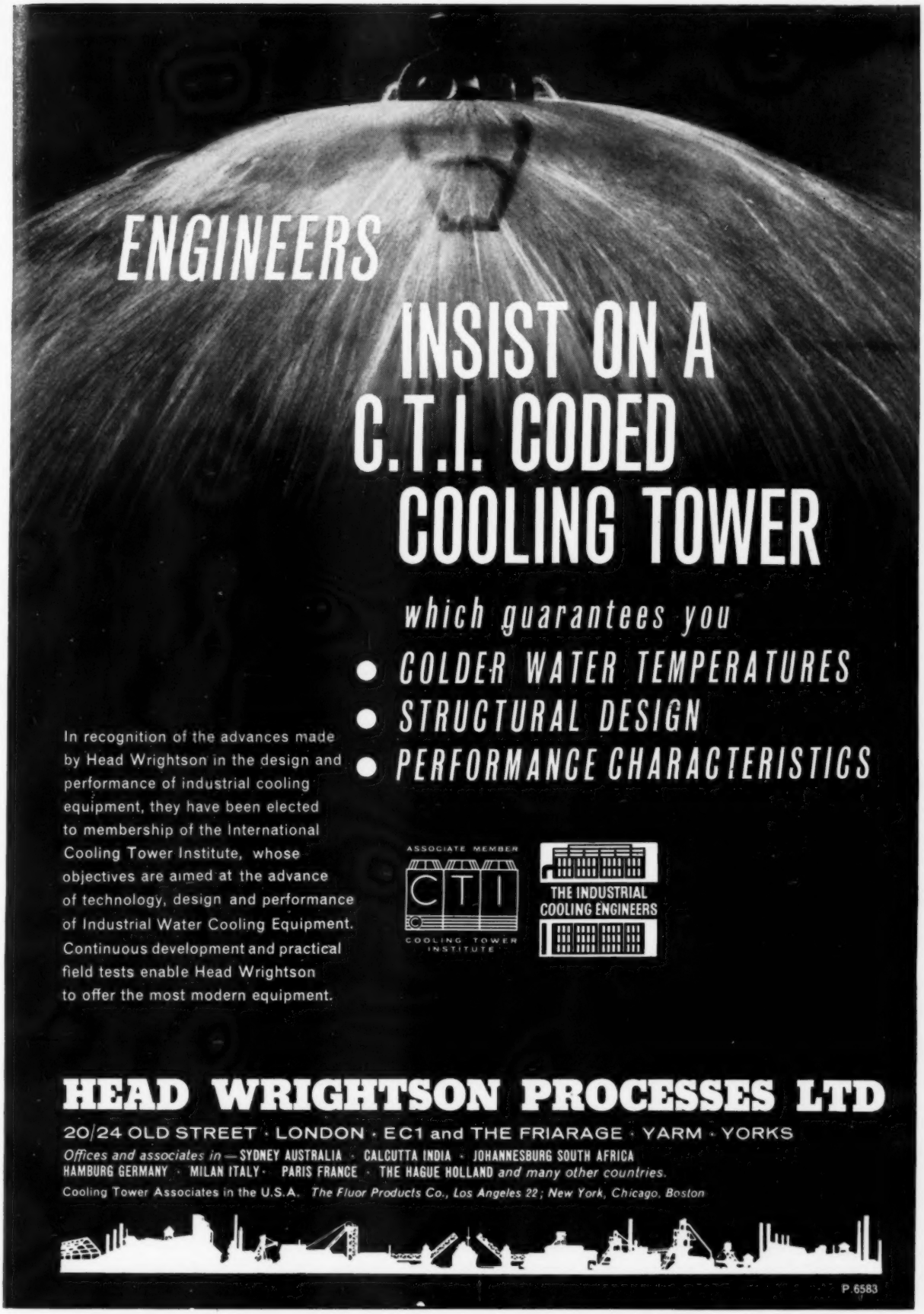
The McCabe-Thiele design method is widely used in distillation problems. An alternative method—the cascade theory of separation processes—was extensively developed for isotope separations.

Characteristics of the ideal cascade are high vapour rates at the feed point that decrease at both ends of the tower. For difficult separations in multiple units, cascade theory can be used to minimize investment, and determine how existing equipment can best be used in a new service. 8 refs., 2 diags., 1 chart.

W. D. MACLEAN, *Chem. Eng.*, 1961, **68** (17), 123-5.

* Author's abstract.

Brit. Chem. Eng. Abstracts: **FOLIO No. 37**



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P.6583

Abstracts

GROUP A — FLUID DYNAMICS (contd.)

Hydraulic Resistance of Pipe Bends to the Flow of a Gas-liquid Mixture

The local hydraulic resistance in pipe bends significantly increases with the increase of the relative gas content of the gas-liquid mixture. Furthermore, the hydraulic resistance depends on the spatial orientation of the bend. For example, when the stream turns from a horizontal direction to a vertical upward flow the pressure drop in the pipe bend is less than it is for the case when the flow direction is changed from the horizontal to vertically downwards. The article is well documented with experimental results.

M. A. PESHKIN, *Teploenergetika*, 1961 (6), 79-80.

Effect of the Gas Flow Direction on the Hydraulic Resistance of Apparatuses

In this short communication the author describes the possible reduction of the pressure drop across any heat or mass transfer apparatus by arranging the flow of the gas and the liquid phases in parallel. If in a packed column both phases are made to move downwards and the gas velocity is in the region of 2-10 m/sec, then the pressure drop decreases 10-20 times. This type of operation is recommended in those cases when the moving force of the process is small. The smaller pressure drop and the absence of flooding permits to step-up the throughput in the apparatus. This increased throughput is associated with more vigorous turbulence and consequently more efficient heat or mass transfer. 8 refs.

L. IA. ZHIVAIKIN, *Khim. Prom.*, 1961 (4), 58-9.

Molecular Transport Properties of Fluids

Experimental and theoretical studies have recently extended the ranges of temperature and pressure over which fluid properties are known. In this review article the author reviews recent work on viscosity and thermal conductivity of fluids. 76 refs.

E. F. JOHNSON, *Ind. Eng. Chem.*, 1960, **52** (5), 447-50.

Designing Turbulent-flow Systems

The author presents a new correlation which was developed for Newtonian fluids and extended to non-Newtonian fluids. This method is more precise in correlating non-Newtonian turbulent data than any other method known. The application of the method to scaling up is illustrated by three examples. 13 refs., 9 charts.

R. LE BARON BOWEN, JR., *Chem. Eng.*, 1961, **68** (15), 143-50.

The Stability of the Valves of Floating Valve Plates

This paper attempts to explain why the valves of floating valve plates are unstable. After assuming a simple velocity distribution for the gas flow under the valve, an expression is obtained for the force on the valve. Values obtained from this expression agree with experimental results for several gas flowrates. The theory is extended to equations which describe the oscillatory motion of the valve. Again, the agreement between theory and experiment is reasonable and so it is concluded that the proposed simple model explains the unstable nature of floating valves. 4 refs., 1 diag., 5 charts.

R. M. WOOD, *Trans. Inst. Ch. E.*, 1961, **39** (4), 313-17.

Exchange of Deuterium between Hydrogen and Liquid Ammonia

Rates of transfer of deuterium from enriched H_2 to liquid NH_3 containing potassium amide catalyst were measured in the range -40 to $+20°C$. Two types of contactor were used, a rod on which the flow of liquid NH_3 was laminar, and a disc column. At low deuterium concentrations, the exchange is equivalent to absorption accompanied by a pseudo first-order reaction. Reaction occurs mainly in a zone extending only 0.001 in. below the surface. Even so, the rate of exchange is very low owing to the low solubility of H_2 in liquid NH_3. The significance of the results with respect to the development of a large-scale contactor is discussed. 16 refs., 1 flow diag., 4 charts.

P. J. BOURKE and J. C. LEE, *Trans. Inst. Ch. E.*, 1961, **39** (4), 280-8.

Best Methods for Obtaining Flow Data

The article describes the construction of an extrusion rheometer which produces data for scaling up non-Newtonian laminar flow. An account of the procedure which was followed in conducting the tests is also given. 9 refs., 1 fig., 1 diag.

R. LE BARON BOWEN, JR., *Chem. Eng.*, 1961, **68** (17), 119-22.

Transport Phenomena Simplify Transfer Theories

Even more fundamental to industrial processes than the classification of unit operations is a set of underlying principles of engineering. The fundamentals of mass, heat and momentum transfer are similar and a combined study of these will simplify the study of unit operations as well as give greater insight into the fundamentals. 12 refs.

L. D. SMOOT, *Chem. Eng.*, 1961, **68** (17), 126-30.

Modern Methods of Dispersing Titanium Dioxide

This short article describes two methods of dispersing TiO_2 in oils by converting it by surface chemical treatment into a hydrophobic pigment. 5 refs.

ANON., *Chemical Products*, 1961, **24** (9), 378.

Factors Affecting the Performance of Valve Plates

This is an experimental investigation of the pressure drop, efficiency and leakage characteristics of valve plates, using the air-water system. There are two stable conditions of the valves, fully open and shut, and at intermediate gas velocities the valves oscillate between these positions. At high gas velocities, when all the valves are fully open, the dry-plate pressure drop agreed with a correlation derived from work with a single valve. At lower velocities, when some of the valves are closed, the pressure drop equalled the valve weight divided by the orifice area.

The plate efficiency was fairly constant for air velocities ranging from 2-7 ft/sec and decreased at lower velocities. Changes in the valve opening from $\frac{3}{16}$ in. to $\frac{1}{4}$ in. had little effect on the efficiency, but there was significant increase when the weir height was raised from $1\frac{1}{2}$ in. to 3 in. Leakage of liquid through the orifices was a maximum at an intermediate gas velocity, when the valves were oscillating between the open and closed positions. The rate of leakage could be reduced by using heavier valves. 6 refs., 4 diags., 16 charts.

W. S. NORMAN and G. J. GROCOTT, *Trans. Inst. Ch. E.*, 1961, **39** (4), 305-11.

Viscosity Temperature Characteristics of Oils

Most of the standard viscosity temperature laws require that $\left(-\frac{1}{\eta_t} \cdot \frac{d\eta_t}{dt}\right)$ should be a simple function of the temperature, where η = viscosity and t = temperature. This was found not to hold outside a limited temperature range. A much better correlation is obtained by plotting the logarithm of the derivative $\log\left(\frac{d\eta_t}{dt}\right)$ against $\log(\eta)$. The significance of this for an index of viscosity is discused in this paper. 3 refs., 4 charts.

A. CAMERON, *J. Inst. Pet.*, 1960, **46** (434), 56-60.

Steam Injection Heating

Steam injection is the fastest and simplest means of heating. Steam flows into the liquid in jets which are tangential to the cross-section of liquid and nearly normal to the direction of liquid flow. The steam jets pulse in the low audio range. The average time of condensation is a few milliseconds. The simple injector described in this paper is claimed to be as effective as more complicated devices.

A. I. MORGAN, JR., and R. A. CARLSON, *Ind. Eng. Chem.*, 1960, **52** (3), 219-20.

Effects of Composition and Vapour Velocity upon the Efficiency of an Oldershaw Column

An Oldershaw column has been operated with the systems (a) methanol-water, (b) ethanol-water and (c) water-acetic acid, and overall efficiencies have been measured at a number of compositions and vapour velocities. Variations in efficiency with composition and vapour velocity are attributed to the presence of surface tension gradients at the interface. With any given mixture, maximum efficiency was obtained when the vapour velocity was so low as just to allow liquid to seep through the perforations in the plates. 20 refs., 3 diags., 3 charts, 4 tables.

S. R. M. ELLIS and R. J. BENNETT, *J. Inst. Pet.*, 1960, **46** (433), 19-25.

Coalescence and Redispersion of Liquid Droplets in a Continuously Agitated Vessel

The overall rate of homogeneous reaction, $2FeCl_3 + SnCl_2 = 2FeCl_4$, in aqueous droplets dispersed in continuous benzene-phase in an agitated vessel has been measured experimentally to determine the extent to which the aqueous droplets coalesce and redisperse during the mean residence-time of the dispersed phase. An agitated vessel was operated continuously. Aqueous $FeCl_3$ and $SnCl_2$ solutions were continuously fed and aqueous reaction product continuously removed.

The experiments showed that coalescence and redispersion of the dispersed aqueous phase is negligible under the conditions of these experiments. 9 refs., 2 diags., 5 charts.

H. MATSUZAWA and T. MIYAUCHI, *Chem. Eng., Japan*, 1961, **25** (8), 582-7.

Brit. Chem. Eng. Abstracts: **FOLIO No. 38**

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Abstracts

GROUP B — HEAT TRANSFER

Experimental Comparison of the Efficiency of Finned Tube and Smooth Tube Liebig-type Heat Exchangers when Working in Oil Media

Finned tube heat exchangers are well established in practice for heat transfer to and from gases. The possibility of a new application in the oil industry is considered here, namely with liquid media both inside and outside the finned tube. Many experiments were carried out with oils of different viscosities at various temperatures. A tube 6 m long, 48 mm nominal bore, having twenty longitudinal fins 1 mm wide by 12 mm high was used in the experiments. Based on the test results, this type of finned tube is suggested for heating oil inside the tube when the outside oil has a kinematic viscosity of 15-20, and the inside oil about 2 centistokes; and for cooling oil inside the tube when the outside viscosity is 3-4 and the inside 1-2 centistokes. 5 refs.

A. B. PLETNITSKAIA, *Khim. Mash.*, 1961, **1**, 17-22.

A Generalized Method for the Estimation of Heat of Vaporization

This generalized correlation is developed from the Clausius-Clapeyron equation. Its accuracy is not as good as was hoped. However, it provides accurate data for Argon, H_2S, CCl_4, SO_2, O_2, CO, N_2, Freon, CS_2. It is not suitable for Cl, CO_2, SO_3, HCN and HCl. 1 chart.

C. ST. PIERRE and CHI TIEN, *Can. J. Ch. E.*, 1961, **39** (4), 170-1.

Heat Transfer in Soldered Packed Bed

Attempts were made to increase the heat transfer in a packed bed by soldering all contact points by pouring fused solder into the packed bed kept at a high temperature. The overall heat transfer coefficients of the soldered packed bed, and the pressure drop, did not change much for the same flow of air. The Nusselt number was correlated by two empirical equations:

(a) for the soldered bed:

$$\frac{D_p\, h_0}{k_g} = 1.26 \left(\frac{D_p\, G}{\mu(1-\varepsilon)}\right)^{0.576} \left(\frac{D_p}{D_t}\right)^{-0.28}$$

(b) for the non-soldered bed:

$$\frac{D_p\, h_0}{k_g} = 0.778 \left(\frac{D_p\, G}{\mu(1-\varepsilon)}\right)^{0.576} \left(\frac{D_p}{D_t}\right)^{0.22},$$

where D_p and D_t = particle and tube diameter; h_0 = overall heat transfer coefficient; k_g = thermal conductivity of gas; G = mass velocity; μ = viscosity; ε = void fraction of packed bed. It was found that the number of contacts formed for each ball were six instead of eight, as had often been assumed in theories on hold up. 2 refs., 3 diags., 10 charts.

S. TAKEOKA and N. NAGASAKO, *Chem. Eng., Japan*, 1961, **25** (8), 588-93.

Problems of Heating the End Flues of Coke Ovens

The brickwork of the end flues of coke ovens becomes damaged before that of other parts of the coke oven. The preservation of oven ends depends mainly on increasing the heat supply to the end heating flues.

The temperature of the end flues should be <100°C lower than those in the control flues. The paper discusses how this can be achieved. 1 diag., 4 tables.

S. I KAFTAN and G M. VOLFOVSKII, *Coke & Chem. (U.S.S.R.)*, 1961 (4), 24-8.

Pilot-plant Preparation of Stereospecific Rubbers

This article discusses the problems of heat transfer, fluid flow and drying of polymers such as polybutadiene and polyisoprene as studied in a scraped-wall reactor with draft tubes. In this unit the heat transfer was greater than in conventional jacketed reactors. 4 refs., 1 diag., 3 charts, 6 tables.

F. L. KUCHINSKI and F. T. MURASKI, *C.E.P.*, 1961, **57** (8), 62-6.

High-velocity Combustion Applied to Chemical Processing—Part 2

The author briefly discussed the application of high-velocity burners to incineration of waste chemicals and fired heat exchangers. Another application is in submerged combustion and inert gas generation.

L. C. PESKIN, *C.E.P.*, 1961, **57** (8), 82-4.

A Review of Heat Transfer Literature, 1960

This review is arranged under the following headings: conduction, channel flow, boundary layer flow, flow with separated regions, transfer mechanism, natural convection. 230 refs.

E. R. G. ECKERT *et al.*, *Mech. Eng.*, 1961 **83** (7), 34-42.

GROUP C — MASS TRANSFER

Co-current-type Contact Plate for the Interaction of Liquid with Gas or Vapour

The authors report some results of the preliminary studies which were carried out on the co-current-type contact plate. The plate is composed of thin grids which are inclined at a small angle (about 9°) to the horizontal, are slightly overlapping and oriented in such a way that the upstream vapour or gas and the down-flowing liquid are contacted in a momentarily parallel flow. Consequently, the loading of the apparatus can be significantly increased and the pressure drop across the plate is small. The column is very stable hydrodynamically and great flexibility of the loading is possible. It can be used efficiently for fractionating or absorption, at atmospheric pressure or under vacuum. Further experiments will be aimed to determine the optimal working conditions of this type of plate and to establish hydrodynamical and mass-transfer correlations. 3 refs.

IU. I. DYTNERSKII and A. G. KASATKIN, *Khim. Prom.*, 1961, **5**, 58-60.

Mass Transfer in Ejector Type Extraction Columns

Three systems were investigated: *o*-xylene-acetic acid-water; dibutylether-acetic acid-water; diisopropylether-acetic acid-water. Water was the dispersed phase, and acetic acid was extracted from the continuous into the dispersed phase in each case. Both phases entered the column through the same type and size of ejector, and the analysis of 46 sets of experiments led to the following correlation:

$$Nu = \frac{1.4}{R^{0.9}}\, Pe_x^{0.95}\, K_x^{1.38} \left(\frac{S_y \,.\, D}{S_x \,.\, W}\right)^{0.5}$$

or after substitution and rearrangement

$$K_y = \frac{1.4}{R^{0.9}} \cdot \frac{W_x^{0.95}\, W_y^{1.38}\, D_y^{0.5}\, \mu_y^{1.38}}{d^{0.05}\, D_x^{0.45}\, (\triangle\sigma)^{1.38}} \left(\frac{\triangle\rho}{\triangle\sigma}\right)^{0.5} \cdot \left(\frac{S_y \,.\, D}{S_x \,.\, W}\right)^{0.5}$$

where K_y = overall mass transfer coefficient, based on the extracting phase; W_x = linear velocity of the continuous phase at the ejector nozzle; W_y = same for the dispersed phase; D_x and D_y = diffusion coefficients for the continuous and dispersed phases respectively; R = partition coefficient; d = column diameter; S_x and S_y = NTU based on the continuous and dispersed phases respectively; D = volume flow rate of the dispersed phase; W = volume flow rate of the continuous phase; μ_y = viscosity of dispersed phase; $\Delta\sigma$ = difference in surface tensions between the phases; $\Delta\rho$ = difference of densities between the phases

N. I. GELPERIN and M. G. ASSMUS, *Khim. Prom.*, 1961, **5**, 52-4.

Ion Exchangers Obtained from Semicoke

The paper describes the production of cation exchangers (sulphocarbons) from semicoke. The sulphonation treatment was as follows: (a) conc. H_2SO_4 at 150, 175 and 200°C; (b) fuming H_2SO_4 containing 20 per cent SO_3 at 100, 125 and 150°C; (c) conc. H_2SO_4 containing 5, 10 and 20 per cent HNO_3 at 125°C.

Conclusions were as follows:

(a) Ion exchange capacity of sulphocarbons from semicoke increases with sulphonation temperature, especially with conc. H_2SO_4. Hence, good exchangers are obtained with conc. H_2SO_4 at 200°C for 3 to 5 hr; at 175°C for 5 to 7 hr; and at 150°C for 7 hr.

Treatment with fuming H_2SO_4 has not produced exchangers having as high a capacity as those produced with conc. H_2SO_4.

Sulfocarbons of good exchange capacity can be obtained with conc. H_2SO_4 plus 10 per cent HNO_3.

(b) The exchange capacity due to carboxylic groups, formed by the action of both HNO_3 and H_2SO_4, increases with temperature and time of treatment. In all cases the carboxylic exchange capacity is greater than the sulphonic by 31.7 to 39.5 per cent for both conc. H_2SO_4 and fuming H_2SO_4 treatment, and by 68 per cent for conc. H_2SO_4 + 10 per cent HNO_3 treatment.

M. DIMA *et al.*, *Bulet. Inst. Politehnic Din IASI*, 1960, VI (X), (3-4), 117-26 (Roumania).

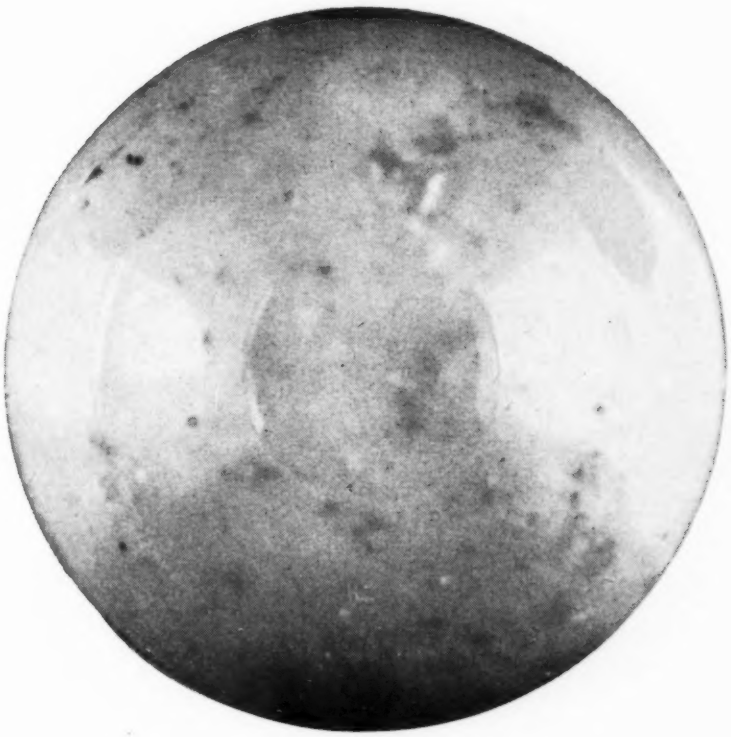
Continuous Solution of Salts in Countercurrent Flow

Mass transfer from KCl and $(NH_4)_2SO_4$ was determined in a vertical tube by throwing the salts into upward-flowing water. The countercurrent flow in the vertical tube was found to be unsuitable on a large scale. Experimental results were expressed in terms of the spatial mass-transfer coefficient, the boundary layer thickness and dimensionless indices. These values can serve as a basis for the design of apparatus for dissolving salts. In a further paper cocurrent solution of salts will be considered. 12 refs., 2 diags., 4 charts.

H. SCHÄFER, *Chemie Ing. Tech.*, 1961, **33** (8), 551-4.

Brit. Chem. Eng. Abstracts: **FOLIO No. 39**

MEET AN ION EXCHANGE RESIN



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AP 64

Abstracts

GROUP C — MASS TRANSFER (contd.)

Mass Transfer With and Without Chemical Reaction

The rates of dissolution of cast solids in a baffled, agitated vessel were determined for the following systems: benzoic acid-water; *o*-salicylic acid-water; benzoic acid-22.5 per cent aqueous glycerol; benzoic acid-41 per cent aqueous glycerol. Measurements were made by a new technique, and the data (for no chemical reaction) were correlated by the method of least squares with the equation $\frac{k^o_L l}{D} = 0.402 \left(\frac{\mu}{\rho D}\right)^{\frac{1}{3}} \left(\frac{r\, d^2 \rho}{\mu}\right)^{0.65}$ with a mean deviation of ±5.8 per cent. These data are considered to agree qualitatively with the turbulent boundary layer concept. Reaction factors k_L/k^o_L were measured for the following systems: benzoic acid-aqueous NaOH solutions; benzoic acid-aqueous KOH solutions; *o*-salicylic acid-aqueous NaOH solutions. These data depended on the ratio of the concentration of reactants, C_B/C_{Ai}, in a manner quantitatively predicted by the boundary layer theory. Reaction factors in diaphragm-type diffusion cells were found to quantitatively support the theory of ion diffusion in a stagnant film. In the above equation k_L and k^o_L are mass transfer coefficients with and without chemical reaction respectively; D is diffusion coefficient; r is stirrer rev/sec; d is stirrer dia.; l is agitated vessel dia.; μ and ρ are fluid viscosity and density. Subscripts A and B refer to solutes A and B, and subscript i refers to the interface. 29 refs., 4 diags., 8 charts.

J. Marangozis and A. I. Johnson, *Can. J. Ch. E.*, 1961, **39** (4), 152-8.

Problems of Fluidized Catalysis—The Conversion Reaction of CO with Water Vapour

The authors examined the influence of bed height and linear gas velocity on the efficiency of the conversion reaction between CO and water vapour, using fluidized catalysts at different temperatures and a wide range of catalyst loadings.

The efficiency rose with increasing height of catalyst bed. The linear gas velocity had no significant influence on the rate of chemical reaction for catalyst loadings of 900-1400 $Nm^3/m^3/hr$.

The relation between contact time and catalyst activity constant for reactions at 360-400°C is represented by equations describing first-order reactions. Above 400°C the results obtained from these equations do not yield constant values indicating a more complicated process. 11 refs., 6 flow diags., 6 charts, 10 tables.

K. Janio and A. Justat, *Chemia Stosowana*, 1961, **V** (2), 261-79.

Desorption of Benzole Hydrocarbons from Wash Oil in Columns with Downfall Plates

A brief account is given in this paper of a pilot-plant study of the desorption of benzole hydrocarbons from wash oil (coal-tar and petroleum). A column with downfall plates was selected after a literature survey followed by trials on such columns. The purpose was to find means of increasing the volumetric output of the columns. 10 refs., 1 flow diag., 7 tables.

A. I. Brodovich *et al.*, *Coke & Chem. (U.S.S.R.)*, 1961 (4), 35-9.

Ion-exchange Behaviour of Acidic and Basic Amino Acids

Some experimental results obtained with ion-exchange of the acidic and basic amino acids are presented and discussed. Amino acids are absorbed on resins predominantly in the pH range near the isoelectric points of the amino acids. Selectivity coefficients were estimated from the dissociation equilibria of amino acids. 3 refs., 7 charts.

M. Seno and T. Yamabe, *Bull. Chem. Soc., Japan*, 1961, **34** (2) 1021-6 (in English).

Selection, Design and Use of Super Refractories in High-temperature Operation

Super refractories are made from silicon carbide, fused aluminium oxide and mullite which are crushed, graded, formed and ceramically bonded. Silicon nitride has recently been used *in situ* to bond silicon carbide crystals. These products offer a wide range of properties: heat conductivity, chemical inertness, resistance to abrasion and thermal shock. High refractoriness is seldom the only reason for selection of a product.

This paper discusses the engineering aspects of selection, design and installation. Three examples are included. 4 refs., 1 fig., 4 diags.

R. W. Brown and R. F. Nering, *Ind. Eng. Chem.*, 1960, **52** (5), 381-4.

Mass Transfer—A Review of Fundamentals

Recent progress in this field has been limited to the modification of existing concepts. This review treats: (a) molecular diffusion and separation processes; (b) mixing processes and turbulent diffusion; (c) diffusion and convection; (d) interfacial resistance and surface phenomena. 82 refs.

C. R. Wilke *et al.*, *Ind. Eng. Chem.*, 1960, **52** (5), 441-6.

Aggregation of Ion-exchange Resin Particles

When H-form cation-exchange resin particles are mixed with the OH-form anion-exchange resin particles significant aggregation takes place. This seems to be due to electrostatic attraction, because aggregation does not occur in a non-polar medium in the complete absence of water. Moreover, the size ratio of particles markedly affects the aggregation. Particles of same size show a maximum aggregation when mixed in equal amounts of H- and OH-form. Particles of different size show a maximum aggregation the greater the proportion of the larger particles and the lesser the proportion of the smaller particles.

A simple explanation is presented to explain this coagulation mechanism. Further observations indicate that virtually no chemical reaction takes place between these particles. 5 refs., 1 fig., 5 charts.

M. Seno and T. Yamabe, *Bull. Chem. Soc., Japan*, 1961, **34** (7), 1002-6 (in English).

CO_2 Gas Absorption by Water Jets Spouted from Rotating Small Holes

This report is the result of fundamental studies on mass transfer in the centrifugal gas-liquid contactor in which liquid is spouted from the small holes drilled through a rotating cylinder wall, and where gas is sent cross-currently to the water jets in an annular space between the rotating cylinder and a stationary concentric outside cylinder.

Many experiments on pure CO_2 gas absorption by water jets spouting from rotating small holes were carried out at 20°C, and the effects of many variables on the liquid mass transfer rate were studied: i.e., dia. of rotor; dia. of small hole, d; number of small holes; width of annular space, δ; gas flow rate, v; liquid flow rate, w; revolution of the rotor, n; time of contact, θ; radius of cylinder, r_1, r_2.

In these experiments, the small hole was 0.5 to 2.0 mm dia., the average velocity of water 55 to 950 cm/sec, and the travelling length of water (the distance between two cylinders), 1 to 5 cm. Under these conditions, the water jet might present laminar flow. Therefore, assuming that the concentrations of gas and liquid were at equilibrium on the interfacial surface, then from the unsteady-state diffusion theory, the mass transfer coefficient of the liquid film $k_L = 2\sqrt{D_L/\pi\theta}$. The contact area per unit volume of water jet, a (cm^2/cm^3), and the liquid film capacity coefficient, k_La (l/sec), were obtained experimentally. As a result, the following equations were derived:

$$k_{LA} = 2a\sqrt{D_L/\pi\theta} = E_{ML}/\theta$$

$$a = 0.0875 \left(\frac{D_L}{\pi\theta}\right)^{-\frac{1}{2}} \cdot d^{-1.2} \left(\frac{r_1 n}{w}\right)^{\beta}$$

$$= 36.5\, d^{-1.2} \left(\frac{r_1 n}{w}\right)^{\beta}$$

where $\beta = 0.72$ for $d \geq 1.0$ mm;
$\beta = 3.93 d^{0.74}$ for $d < 1.0$ mm;
D_L = diffusion coefficient in liquid phase;
E_{ML} = Murphree absorption efficiency.

The gas absorption rate by water was observed to be large immediately after the liquid was spouted from the hole, as predicted from the above equations. Therefore, a practical design of such a contactor would be a multi-rotor-type contactor in order to make as many jets of liquid as possible.

T. Takamatsu *et al.*, *Chem. Eng., Japan*, 1961, **25** (8), 595-602.

Determination of Ternary Liquid-liquid Systems by Use of the Lever Rule

This method is based on a combination of the lever rule and the measurement of a physical property which is a function of composition. The method was tested on toluene-water-acetic acid at 25°C and the results agreed with literature values. A possible modification of the method is also described. 7 refs., 3 charts.

E. L. Heric and K. R. Williams, *Can. J. Ch. E.*, 1961, **39** (4), 165-8.

Principles of Low-pressure Flash Evaporators

The fundamental principles of flash evaporation determine the design and construction of water desalination plants. The author discusses the thermodynamics of these evaporators and indicates various economic cycles. 6 charts, 3 figs.

W. Steiner, *Chem. Eng. Proc.*, 1961, **42** (9), 395-401.

Brit. Chem. Eng. Abstracts: **FOLIO No. 40**

CAPPER COMPLETE BIG PIPEWORK JOB FOR HOOVER

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By installing over 50,000 ft. of pipe ahead of schedule, Capper helped Hoover complete their new Merthyr Tydfil factory, which is the largest washing machine factory in Europe, in time for the launching of their revolutionary new 'Keymatic'. (Main contractors were George Wimpey & Co. Ltd.)

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Abstracts

GROUP E — PROCESSING

Pretreating Uranium for Metal Plating

This patent deals with a process of anodically treating the surface of uranium articles, prior to metal plating, in an aqueous solution of about 10 per cent polycarboxylic acid—preferably oxalic acid—containing from 1 to 5 per cent by weight of glycerine and from 1 to 5 per cent by weight of hydrochloric acid at from 20 to 75°C for from 30 sec to 15 min. A current density of from 60 to 100 amp/sq ft is used.

R. F. Wehrmann, U.S. Pat. No. 2,982,702, issued May 2, 1961.

Process for Descaling and Decontaminating Metals

This patent relates to the method of removing oxide scale from the surface of stainless steels and similar metals by contacting the metal under an inert atmosphere with a dilute H_2SO_4 solution containing chromous sulphate. The removed oxide scale is either dissolved or disintegrated into a slurry by the solution. Preferred reagent concentrations are 0.3 to 0.5 M chromous sulphate and 0.5 to 0.6 M sulphuric acid. This process is particularly applicable to decontamination of aqueous homogeneous nuclear reactor systems.

R. D. Baybarz, U.S. Pat. No. 2,981,643, issued April 25, 1961.

Preparation of Compacts made from Uranium and Beryllium

This patent describes a powder metallurgical method of making high-density compacts of uranium and beryllium. Powdered UBe_9 and powdered Be are blended, compacted and then sintered by rapidly heating to a temperature of approximately 1220-1280°C in an inert atmosphere.

R. P. Angier, U.S. Pat. No. 2,979,399, issued April 11, 1961.

Method and Apparatus for Calcining Salt Solutions

This patent describes a method for converting uranyl nitrate solution into solid UO_3. The solution is sprayed horizontally into a fluidized bed of UO_3 particles at 310° to 350°C by a nozzle of the coaxial air jet type at about 26 psig. Under these conditions the desired conversion takes place and caking in the bed is avoided.

S. Lawroski, A. A. Jonke and R. G. Taecker, U.S. Pat. No. 2,981,592, issued April 25, 1961.

Batch Fractionation of Coal Tar Naphthalene Oils*

The design of batch fractionating columns for the distillation of alkali-washed coal tar naphthalene oils is difficult, because of a lack of data for the systems involved.

Here a semi-empirical method, involving linear plots, is described for establishing the relationship among fractionating column efficiency, recovery of naphthalene, and enrichment of naphthalene for a given oil. The basis of the approach is the correlation of results obtained from a minimum of three laboratory fractionations on columns of known efficiency. 3 charts, 2 tables.

D. K. H. Briggs *et al.*, *Ind. Eng. Chem.*, 1960, **52** (2), 145-6.

Solvent Refining of Low-temperature Tar with Paraffinic Solvents

Solvent refining of low-temp tar was evaluated as an alternative to distillation to recover higher yields of extract. Single-stage batch extraction with paraffinic solvents from propane through hexane was carried out at 100° to 150°C. Extract yields increased with increasing solvent wt, varying from 14 to 90 per cent of the tar. The yield of extract using pentane and hexane increased with increasing temp. The selectivity for rejecting asphaltenes increased as the mol wt of the solvent decreased. H-rich components are concentrated in the extract; O-, N- and S-containing compounds in the reject. Low-temp tar can be separated at higher mol wt levels than is possible by conventional distillation. 1 fig., 3 charts.

M. D. Kulik and M. B. Neuworth, *Ind. Eng. Chem.*, 1960, **52** (2), 141-4.

Processing Low-temperature Lignite Tar

The paper describes work on tar derived by the low-temp carbonization of Sandow (Tex.) lignite. The tar was distilled into fractions, and studies of the composition of the fractions led to dual-solvent extraction of the primary tar.

A 4-in.-diameter rotating disc contactor was used. A pilot plant capable of processing about 1000 gal per day is described. 1 flow diag., 2 figs, 5 charts, 5 tables.

H. R. Batchelder *et al.*, *Ind. Eng. Chem.*, 1960, **52** (2), 131-6.

* Author's abstract.

Nitric Acid Manufacture—Theory and Practice*

The commercial production and use of nitric acid in the U.S. are described. Several variants of the ammonia oxidation process are outlined, and the underlying theory of ammonia oxidation, nitric oxide oxidation and nitrogen dioxide absorption in water is summarized. Recent developments include two methods for producing nearly 100 per cent nitric acid and two methods for direct synthesis of nitric oxide.

H. A. Sorgenti and G. F. Sachsel, *Ind. Eng. Chem.*, 1960, **52** (2), 101-4.

Flash Distillation Plants

This article describes the engineering and operation of both a very large (1 million gal/day) and a very small (10 tons/day) package flash distillation plant for sea-water.

W. Smith, *Chem. Eng. Proc.*, 1961, **42** (9), 391-4.

The Manufacture of Ethylene Oxide

The article reviews some technical aspects of the manufacture of ethylene oxide produced by the two most common processes: (a) the chlorohydrin process, in which ethylene is converted to ethylene chlorohydrin with hypochlorous acid, followed by dehydrochlorination to give ethylene oxide; and (b) the direct oxidation process, in which ethylene is converted to ethylene oxide in one step by reacting it with oxygen or air over a silver catalyst. 9 refs., 2 flow diags.

R. P. Van Oosten, *J. Inst. Pet.*, 1960, **46** (443), 347-51.

The Production and Utilization of Butadiene

This article reviews the following commercial processes: (1) Aldol process. (2) Dehydrochlorination of dichlorobutane. (3) Reppe process based on acetylene. (4) Alcohol dehydration. (5) Butene dehydrogenation process. (6) Butane dehydrogenation process. (7) Cracking process.

Butadiene is utilized in: (1) Production of SBR rubber. (2) Production of N-type rubber. (3) Polybutadiene rubber. 16 refs.

Production of Uranium Metal from UF_6 by Direct Reduction with Lithium or Sodium Amalgam*

On a 3-16 g of uranium per batch scale, at 25 to 50°C, 86 per cent of the UF_6 vapour carried in argon was reduced to UH_{g4} by lithium amalgams containing 133 to 150 per cent of the stoichiometric lithium requirement. The UH_{g4} was decomposed in a vacuum retort to mercury and massive uranium metal. Two tentative flowsheets for continuous production of uranium metal by lithium amalgam reduction were proposed and demonstrated on a 10 g of uranium scale.

In the sodium amalgam reduction of UF_6, the maximum conversion to UH_{g4} was 40 per cent.

The uranium amalgam produced in one run from the reduction of UF_6 by lithium amalgam was processed through all stages to recover 13 g of massive metal, representing 81 per cent of the uranium in the original UF_6. With the exception of mercury, the concentration of all impurities attributable to the method was lower than for electrolytic-grade metal. 4 refs., 3 flow sheets, 1 diag., 1 flow diag., 6 tables.

O. C. Dean, Report ORNL-2770, UC-4-Chemistry, Available from O.T.S., Department of Commerce, Washington, 25, D.C., U.S.A. Price $0.50.

Some Factors in the Safe Operation of Air Separation Units

The proceedings of a meeting at which this topic was discussed in relation to separation of oxygen from air in tonnage oxygen plants. The introductory paper, by J. B. Gardner, outlined those factors mainly for the benefit of those who are concerned with oxygen plant operation.

Chem. Engr. (London), 1961 (156), A43-A63.

25 years of Fisher-Tropsch Synthesis with Fixed-bed Catalysts—Present Position and Future Possibilities

The fixed bed synthesis ($nCO + 2nH_2 = n(CH_2) + 2H_2O$) has particularly progressed since 1946. The author discusses the development of the highly efficient reactor as well as the stoichiometric production and yields of hydrocarbons from CO and H_2. The effect of CO_2, H_2O and S compounds on the synthesis is considered. A method is described for calculating the maximum thickness of the catalyst bed. Catalyst life is doubled by extraction without interrupting the synthesis for regeneration. Catalyst consumption has been reduced to <5 per cent of that in the original reactors. The possibility of producing motor fuels, lub oils and chemical products is also discussed. The economic conditions related to the process are illustrated by examples. 11 refs.

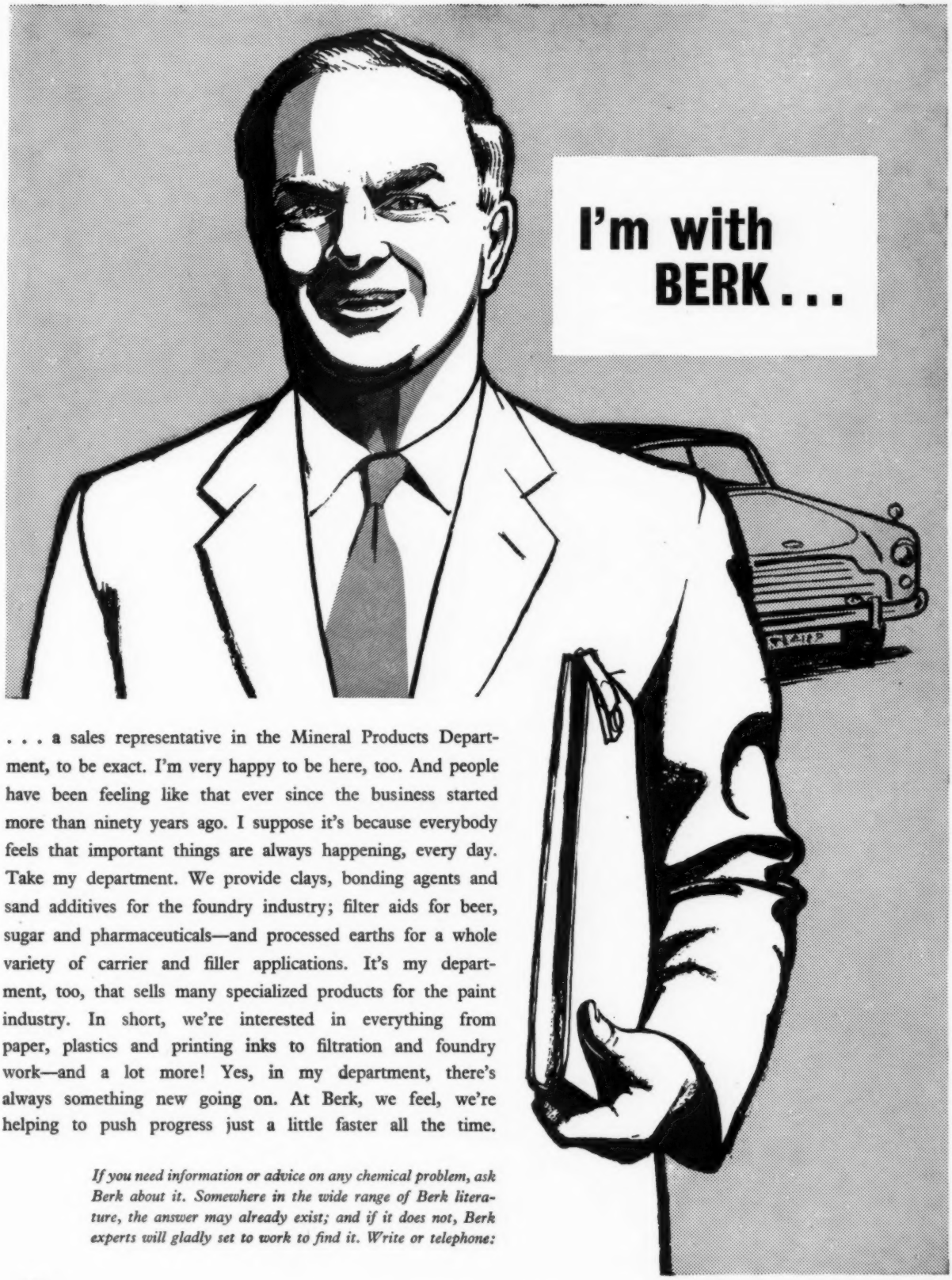
H. Tramm, *Erdol u. Kohle*, 1959, **12**, 347-53.

Surface Treatment of Moulds

This paper summarizes the advantages of using silicone lubricants and colloidal graphite in treating the surfaces of moulds. It stresses the importance of correct application.

J. H. Edgington, *Glass Tech.*, 1961, **2** (4), 140-1.

Brit. Chem. Eng. Abstracts: **FOLIO No. 41**



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Abstracts

GROUP F—PROCESS CONTROL

Minimum Time Control of Second-order Pulse-width-modulated Sampled-data Systems*

This paper treats the minimal time control problem for two second-order pulse-width-modulated sampled-data systems; one with a double integrator type plant, and one with a plant described by an integral and a time constant. Such plants are encountered in systems with hydraulic components. It is shown that for minimal time control the phase plane can be divided into two regions: a striplike region around the optimal switching trajectory for a continuous relay system with the same plants, in which the pulse width must be adjusted for optimal action; and the rest of the phase plane in which an optimal p.w.m. system of the type described behaves like a continuous optimal relay system, the pulse duration being equal to the sampling period. A brief description of an electromechanical computer capable of implementing minimal time control for these systems is also given.

E. Polak, Paper No. 61-JAC-7, presented at the Joint Automatic Control Conference, Boulder, Colorado, June 1961. Available from A.S.M.E., 29 West 39th Street, New York, 18.

Optimal Control Methods for On-off Sampling Systems*

This paper considers the problem of optimal (minimum-time) on-off regulation of a dynamic plant whose state is known only at periodic instants of time. It is shown that on-off control inputs which change value only at the sampling instants inherently lack the capability of providing accurate (dead-beat) control. If, however, the on-off controller is modified to include pulse width control, it not only has the capability for accurate control, but also has the capability for optimal control comparable to that of a saturating amplifier controller. In addition, the optimal pulse width control inputs can be specified as a function of the state of the plant at each sampling instant. The application of this method is discussed in detail for the cases of pure inertial and second-order underdamped plants.

W. L. Nelson, Paper No. 61-JAC-6, presented at the Joint Automatic Control Conference, Boulder, Colorado, June 1961. Available from A.S.M.E., 29 West 39th Street, New York, 18.

Cost Models for Control Systems Engineering

The use of cost model relationships will determine significant economic factors in connection with control systems. Long-term cost models help to justify the overall investment in automatic control costs. Medium and short-term cost models provide information for obtaining the greatest net return on a system being controlled.

H. Chestnut, Paper No. C.P. 61-707, presented at the Joint Automatic Control Conference, Boulder, Colorado, June 1961. Available from American Inst. Elect. Eng., 33 West 39th Street, New York, 18.

Design of Non-interacting Control Systems using Bode Diagrams*

A systematic design procedure has been developed for non-interacting control of multivariable systems. Unlike previously proposed design techniques, which are mostly based on closed-loop complex-frequency transfer functions, this method is based on open-loop real-frequency Bode diagrams. The advantage of the method is that considerations of control specifications, physical realizability and stability can be included in the design procedure in a simple manner. Such simplicity in design is essential for non-interacting control for large realistic systems, where digital computational aid is indispensable.

K. Chen, R. A. Mathias and D. M. Sauter, Paper No. 61-708, presented at the Joint Automatic Control Conference, Boulder, Colorado, June 1961. Available from American Inst. Elec. Eng., 33 West 39th Street, New York, 18.

A Graphical Method for Finding the Frequency Response of Non-linear Closed-loop Systems*

This paper presents a graphical procedure for finding the frequency response of a large class of systems for which the describing function provides an adequate representation for the non-linear elements. Attention is restricted to frequency-insensitive, zero-memory non-linear elements. The method is direct, requiring only an understanding of the point of view, and it can be extended to cover systems containing more than one non-linear element.

A. S. McAllister, Paper No. 61-710, presented at the Joint Automatic Control Conference, Boulder, Colorado, June 1961. Available from American Inst. Elect. Eng., 33 West 39th Street, New York, 18.

* Author's abstract.

GROUP H — DESIGN

Fabrication of Dished Ends using the Energy of Explosion

An interesting process is described in this paper. The simplicity of the equipment required makes possible a significant reduction in the cost of fabricating dished ends. In the course of investigations dished ends of different grades of stainless steel and aluminium alloy were made. Two processes are mentioned: according to the first method, the dished end is formed by one explosion; according to the second method it is formed in two steps, i.e., the first explosion forms the spherical part and the next forms the knuckle radius. It is shown how the necessary quantity of explosive and the final pressure required can be calculated. For example, 80 g gunpowder were required (less if a trotyl-compound is used) to form a 1600-mm-diameter stainless-steel standard dished end, and the resulting 44 atm pressure provided optimum conditions. Every dished end which was produced by using the method of utilizing the energy of explosion was of uniform, high quality. 4 refs.

V. G. Kononenko, *Khim. Mash.*, 1961 (1), 34-6.

Chart Gives Furnace-heat Evaluation

A rapid and simple method is described for evaluating furnace-heat transfer data without resorting to long, exact calculations. 1 chart.

Anon., *Pet. Ref.*, 1960, **39** (1), 196.

Design of Thermosiphon Reboilers

This report describes a step-by-step procedure which is claimed to produce a more reliable design of thermosiphon reboiler. Some principles outlined here also apply to other types of reboiler. Two examples illustrate the method. 40 refs., 1 flow diag., 11 charts, 6 tables.

J. R. Fair, *Pet. Ref.*, 1960, **39** (2), 105-23.

Design Heat Exchanger Piping

This article presents details of exchanger layout and piping design showing how to save labour and material costs, by reduced maintenance and improved operation. Many figs. and flow diags.

R. Kern, *Pet. Ref.*, 1960, **39** (2), 137-52.

A Mathematical and Experimental Study of a Climbing Film Evaporator

In this work measurements were made of variables that govern the performance of a climbing film evaporator, and expressions were derived for their prediction. A theory based on the Navier Stokes force balance predicts the film thickness, volume hold-up and hold-up time. An expression was derived for power requirements. In addition, heat transfer coefficients were measured. These expressions can be used for the design of climbing film evaporators. 1 flow diag., 1 chart.

G. F. Hadley and A. L. Thomas, *Ind. Eng. Chem.*, 1960, **52** (1), 71-4.

Design of Ports and Manifolds in Thermal Diffusion Columns

The efficiency of heat utilization in continuous-flow thermal diffusion columns can be improved by designing inlet and outlet ports so as to achieve a uniform lateral distribution. The paper discusses the proper design of such ports. 4 refs., 4 diags.

J. R. White and A. T. Fellows, *Ind. Eng. Chem.*, 1960, **52** (5), 389-90.

Design of Aluminium Tanks for Transport of Liquid Methane

The author describes a prototype ship of 5000 tons for transporting liquid CH_4. A 30,000-ton vessel carrying 10,000 to 15,000 tons of liquid CH_4 would be more economical. Insulation, mounting, ballasting and safety aspects are considered and Al alloy is shown to be a suitable material of construction. Rectangular tanks are shown to be the most suitable.

W. Ferguson, *Petroleum, London*, 1961, **23**, 231, and *Fluid Handling*, 1961, 193-7.

New Machines, Apparatuses and Equipment

In this regular feature of the journal some new items are briefly described together with a diagram and relevant technical data. The following are reviewed in this article: (a) A continuous centrifugal separator of 10 m^3/hr capacity which was developed primarily for the oil industry to separate oil emulsions. (b) Also for the oil industry is a new type of shell-and-tube heat exchanger made of an aluminium alloy which is 4-6 times less prone to attack by sulphurous compounds than steel. The tubes are provided with longitudinal fins, thus improving the heat transfer by nearly 40 per cent. (c) Several new turbomixers have also been developed for many duties in solid-liquid, liquid-liquid and gas-liquid mixing, when the liquid viscosity does not exceed 5 poise.

Khim. Mash., 1961 (2), 48-9.

Brit. Chem. Eng. Abstracts: **FOLIO No. 42**

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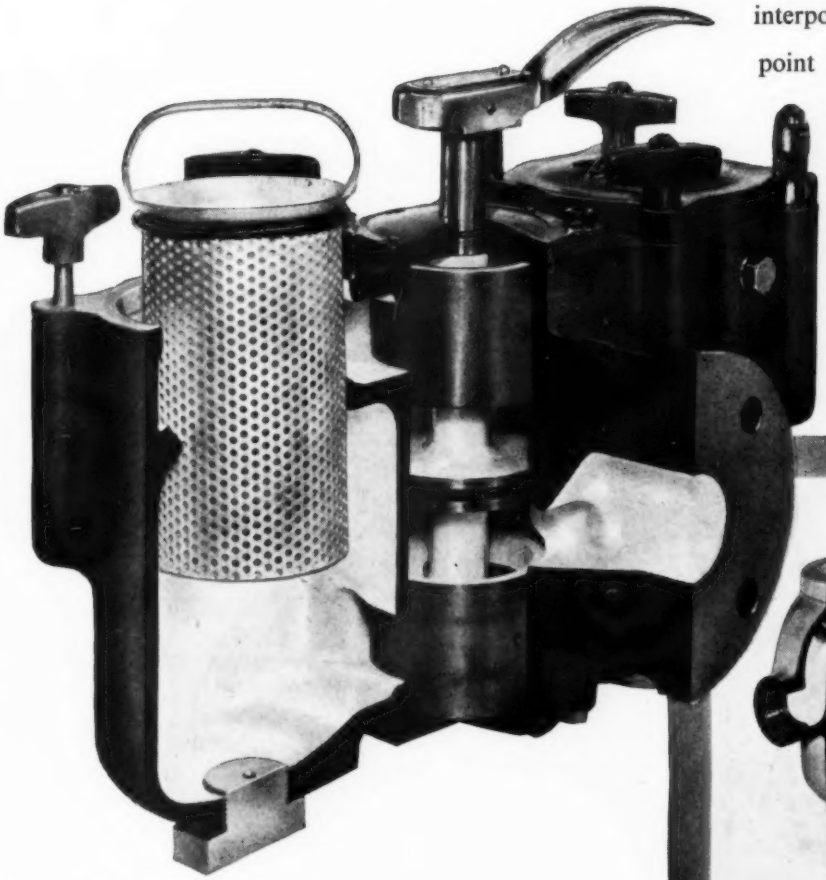
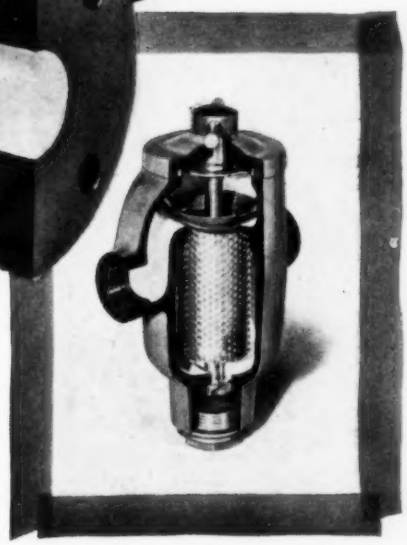


Left: A 2" BIPLEX Filter unit

Below: A 1½" UNIPLEX Filter unit



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HEAT TRANSFER COEFFICIENT IN PNEUMATIC TRANSPORT LINES

by G. NARSIMHAN, Ph.D., National Chemical Laboratory, Poona 8, India

A nomogram is constructed for the calculation of heat-transfer coefficient in pneumatic transport lines. The following equation[1] is used in the construction:

$$\frac{h \cdot D_t}{k} = 0.16 \left(\frac{D_t \cdot G}{\mu}\right)^{0.6} \cdot \left(\frac{C_p \cdot \mu}{k}\right)^{0.4} \cdot \left(\frac{G_s}{G}\right)^{0.45}$$

where h = the film coefficient, Btu/hr ft² °F;
Dt = the diameter of pipeline, ft;
k = thermal conductivity of carrier gas, Btu/hr ft °F;
μ = viscosity of carrier gas, lb/ft hr;
C_p = heat capacity of carrier gas;
G = mass velocity of carrier gas, lb/ft² hr; and
G_s = mass velocity of solids, lb/ft² hr.

The nomogram is made up of a combination of parallel and proportional scales. All the four scales, *A*, *B*, *C* and *D*, in the proportional chart are double scaled. The following example will serve to illustrate the procedure to be adopted in using the nomogram.

Problem

An inorganic material (sp. mass 2.5) is being pneumatically transported at 100°C in a pipeline of internal diameter 2.4 in. Air is the carrier gas. The air mass velocity is 10,000 lb/ft² hr and $\left(\frac{G_s}{G}\right)$ ratio is 5. Calculate the effective air film coefficient. The following physical properties are taken from Hand-book.

k = 0.018 Btu/hr ft °F;
μ = 0.021 c.p.;
C_p = 0.25.

Procedure

1. Locate l on the extreme right μ scale and m on C_p scale. Join to intersect M scale at n. Locate p on the k scale. Join n-p to intersect B scale at q. Locate q again on the uniform B scale.

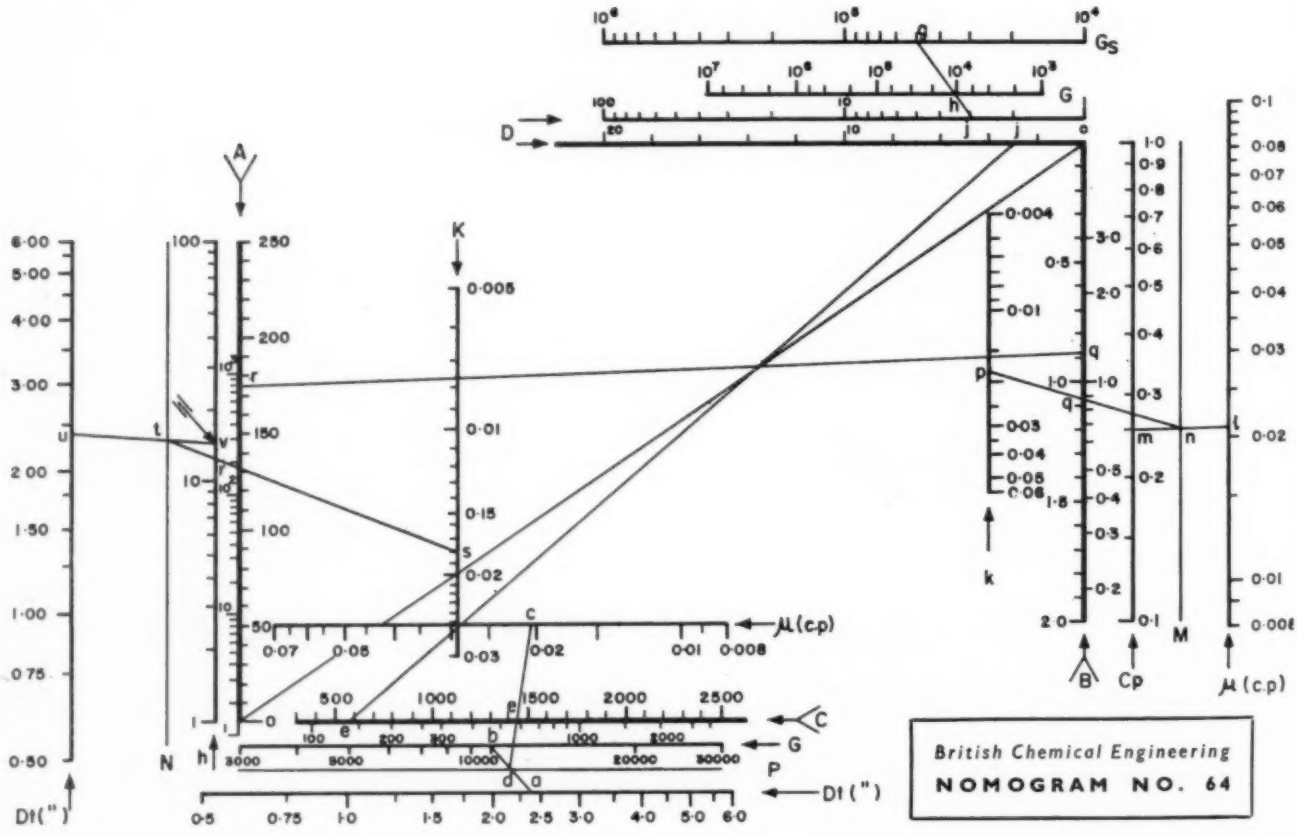
2. Locate g and h on the top G_s and G scales respectively. Join and extend to intersect D scale at j. Locate j again on the uniform D scale.

3. Locate a and b on the bottom D_t and G scales respectively. Join to intersect P scale at d. Locate c on the μ scale. Join d-c to intersect C scale at e. Locate e again on the uniform C scale.

4. Join points j and e to intersect the diagonal 0-0. Draw a line connecting q and the point of intersection. Extend to locate r on the uniform A scale (on the right). Locate r again on the log scale (left). Locate s on the K scale. Join s-r and extend to intersect N scale at t. Locate u on the D_t scale. Join u-t and extend to intersect the h scale at V.

The heat-transfer coefficient indicated by V is 15.0. The calculated value from equation is 14.8.

REFERENCE
[1] "Fluidization", by Max Leva, McGraw-Hill Book Co., New York. (1952), 232.



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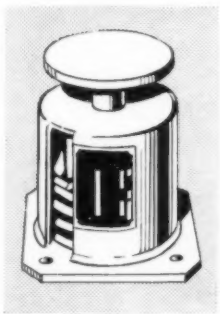
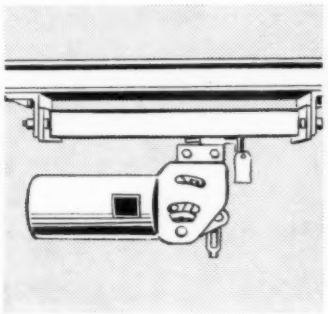
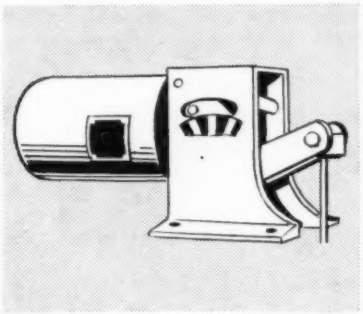

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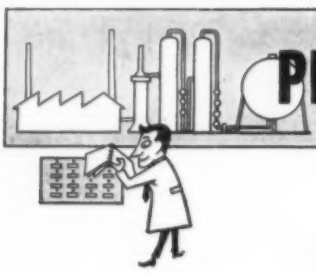


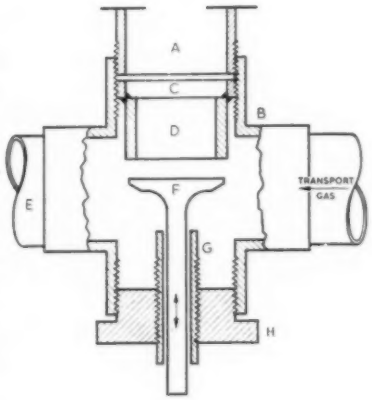
PROCESS ENGINEER'S NOTEBOOK

An Improvised Solid Flow Control Valve

THE diagram shows how a simple, but successful, solid flow control valve was made for introducing a granular solid into an experimental pneumatic transport system. The main feature of the arrangement is the use of a discarded motor-car valve as the effective working part.

The transport system comprised a 2-in. B.S.P. standpipe (A), connected to a 2-in. B.S.P. transport pipe (E) by means of a 2-in. B.S.P. cross (B). A short length of 2-in. B.S.P. nipple (C), to which was welded a short length of 1¼-in. B.S.P. pipe (D), was screwed down into the upper limb of cross (B) as shown. The lower end of pipe (D) was ground flat and smooth before insertion. This arrangement restricted the opening of the standpipe into the cross to a diameter of 1¼ in., which was ¼ in. less than the diameter (1½ in.) of the flat face of the valve head available. The valve (F) was arranged in the position shown, through the lower limb of the cross (B), so that the valve could move vertically up to and away from the lower end of the standpipe opening. The stem of the valve passed through a 3-in. length of pipe (G), whose bore had been selected to give a good sliding fit (⅛-in. B.S.P.). Pipe (G) was screwed through a 2 in. × ¾-in. B.S.P. reducing bush (H), which was in turn screwed into the lower limb of cross (B). Adjustment of the range of travel of the valve was obtained by screwing pipe (G) into or out of bush (H) as desired.

The valve was operated in this particular instance by a two-way air cylinder connected to the lower end of its stem. The air cylinder was actuated by signals received from a capacity probe installed in the standpipe (A), where a constant head of material was maintained. The action of the valve was therefore intermittent, but the average rate of flow could be controlled closely by adjusting the range of travel as described above. However, a proportional mode of operation could equally well be applied by connecting the valve stem to a diaphragm motor actuated by a pressure controller and differential pressure cell tapped across the standpipe.



Economical Arrangement of Instrumentation in Pilot-Plant work

WHEN providing the instrumentation for a new pilot plant, it is often worthwhile considering whether to install the "instrument lines" (i.e., thermocouple leads, purges and pressure impulse lines) on a two-way basis.

A pilot plant being erected by the author comprised several units which were untried; it was visualized that some augmentary work would be necessary also for testing mock-up components of the main plant. As the instruments (temperature recorder/controllers and pressure recorder/controllers) were expensive and strict budget limitations applied, it became necessary to use the main instrumentation for both purposes.

This was conveniently arranged by:

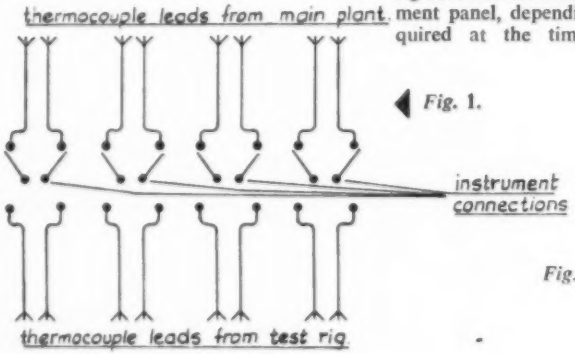
(1) installing two-way switches in the thermocouple lead lines (Fig. 1); and

(2) installing small cocks in the purge and pressure impulse lines (Fig. 2).

Thus either the main plant or the test-rig could be connected to the same instrument panel, depending on which was required at the time. The change-over procedure was simplified by mounting the switches and valves vertically above one another, so making it possible to change from one system to the other by simple upward or downward sweeps of the hand.

This principle of common instrumentation could be extended to include common service connections (with short branch lines to each plant), common support structure, common effluent and product disposal systems as well as common instrument panel for two like pilot plants of differing scale and thereby reduce development costs.

W.H.N.



◀ *Fig. 1.*

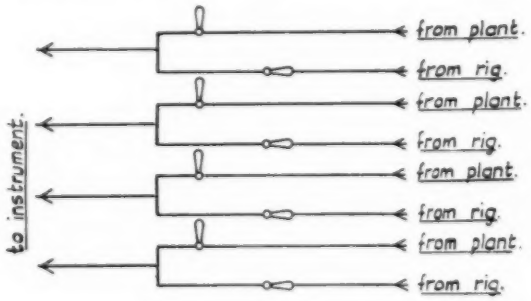


Fig. 2 ▶

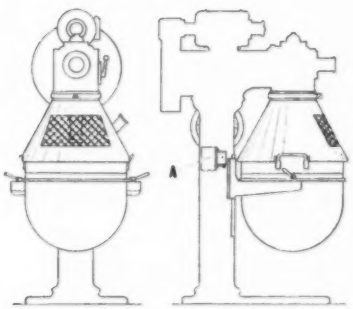
Safety in Mixing Machines and Tilting Pans

IT often happens that a machine designed for use in a particular application may be required for use for an entirely different process. In these circumstances it is well to ensure that hazards absent in the initial application do not arise in the new application.

A case in point has been described recently when an intensive mixer for preparing thick pastes of dough-like consistency was used for the mixing of refractory materials.* The open mixing pan was carried between two arms, and the pan could be raised or lowered at will. During a demonstration of the machine it was stopped for the removal of a sample for a moisture check, and while this was being done the starter button was depressed through a misunderstanding on the part of the unskilled operator who had been shown at the time how to carry out the sampling procedure. As a result, the agitator severely damaged the hand of the demonstrator. Following this incident, a number of improvements were made on the mixer:

(a) A conical fixed guard was fitted so as to form a complete enclosure at the top of the mixing bowl.

(b) An electro-magnetic interlocking switch, A, was provided and arranged so that the beater of the mixer could only be set in motion when the mixing bowl and its contents was in the raised position and such that the beater itself was inaccessible.



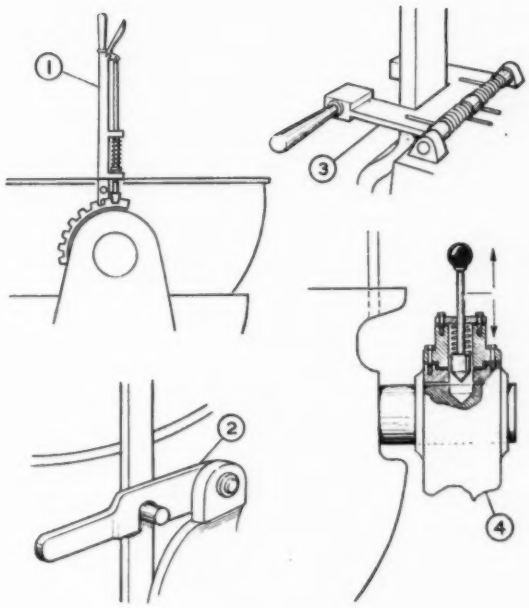
(c) A transparent window was provided so that the movement of the beater could be seen, and this window had mechanical protection by way of a suitable mesh guard.

(d) A tube was inserted in the conical guard so that liquids could be added without danger and this also offered an opening through which small samples could be extracted.

(e) When it was necessary to gain access to the final mix then the bowl could be lowered, but this caused the power to the beaters to be cut off.

(f) The interlock was arranged so as to prevent misuse.

(g) The mixing bowl was secured in position on its supports when the mixing operation was in progress so as to prevent accidental displacement.



Tilting pans are another type of apparatus widely used in batch processing, and for safety it is essential that inadvertent tilting is prevented. For this purpose various kinds of lock are available. One relies upon a worm and worm wheel, while others include a toothed segment with spring-loaded lock (1), heavy metal latch (2), spring-loaded clip (3) and spring-loaded locking pin (4) in the case of small units.

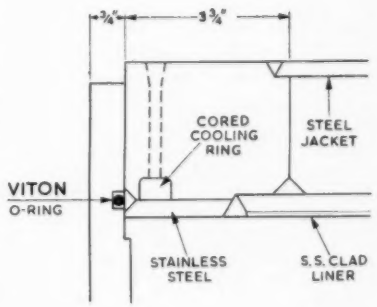
* *Accidents*, **48**, 27-29 July, 1961. H.M.S.O., London.

O-Rings as Gaskets on Vacuum Driers

PROCESSING requirements of a horizontal, agitated, high-temperature, vacuum drier, specially designed for a chemical plant near Camden, N.J., U.S.A., called for an acid-resistant stainless-steel lining in the drier and a Dowtherm-heated jacket around it. The end-plate gasket had to withstand Dowtherm heat transfer fluid condensing at 300°C, to which it would be exposed continuously for 36 hours per manufacturing cycle. At the same time the gasket had to effect a seal against the acidic reaction components.

The problem was solved by a dual mechanical-chemical combination. This consisted of a steam-fed, cored cooling ring 3¼ in. wide, welded around the drier shell at each end of the jacket to remove some of the heat that would otherwise have been transmitted directly through metal to the end gaskets, and a heat- and acid-resistant fluoro-elastomer O-ring for the seal. These seals are expected to last as long as the equipment, since to replace them would be a major project.

The unit has now operated several hundred hours without a hitch, thus confirming the suitability of these seals which are believed to be the world's largest



Book Reviews

The Foundations of Chemical Kinetics
by S. W. Benson
McGraw-Hill Co. Inc., New York, 1960, 703 pp., 104s. 6d.

TAKING a chemical reaction from the laboratory and converting it to a plant process requires three stages: first, the preparation of material and energy balances for the proposed process, and the determination of process conditions and reaction times; second, the determination of process specifications, and the equipment required to contain the process; and, third, the selection of materials of construction and the mechanical design of the plant. The first stage, that of primary development, consists of the stoichiometry, thermodynamics and kinetics of the processes involved, and the last of these is unfortunately the most difficult and the least taught in chemical engineering courses. "The Foundations of Chemical Kinetics" is a text-book intended for advanced undergraduate and post-graduate instruction in chemistry, but the treatment is such that it can also give a firm basis for a kinetics course for chemical engineers at the advanced and post-graduate levels where at present no specific text-book is available.

The book gives a thorough theoretical basic treatment of chemical kinetics as it is understood at present, and in addition provides a contemporary review of experimental reaction studies. The twenty-seven chapters are divided into four groups. The first covers exact description of reacting systems, the mathematical treatment of kinetic measurements for simple and complex reactions, and the principles involved in the experimental study of reaction rates. The second group gives a simple treatment of the kinetic theory of gases leading to a discussion of transport properties and an introduction to statistical thermodynamics. The third group of chapters—almost 300 pages—is a text-book in its own right on gas phase reactions. There is throughout a concentration of attention on the details of the mechanisms of the reactions, which, it is stressed, must be consistent with the kinetics, but cannot be established by kinetics alone. The last group deals with reactions in condensed phases, and includes a chapter on heterogeneous reactions. Various physical models for solution reactions are discussed, together with their limitations. It also includes the only section on reaction kinetics at high pressures, to be found outside special monographs, to be published since 1941. There is a brief but comprehensive treatment of the theory (up to 1958), together with the important reactions and equilibria studied experimentally. There are also sections on acid base catalysis and linear free energy relations. A problems section has been included, the last problem being particularly intriguing, as it requires the student to find recent research papers on kinetics and pull them to pieces.

This is a large book—and therefore rather expensive—but it is not only an invaluable text for reference by teachers of kinetics, but will form a reservoir of information for those engaged in process evaluation in research and development laboratories.

W. STRAUSS

Wärmeaustauscher
by Prof. Dr. Ing. Romano Gregorig
Verlag H. R. Sauerlander & Co., Aurau and Frankfurt/M., 1959, 500 pp.

THIS is Volume IV of the series "Grundlagen der Chemische Technik" edited by PROF. MOHLER and FUCHS in Switzerland. This volume deals with heat exchangers in all aspects of design, construction, manufacture and operation and in this respect it differs somewhat from the well known text-books on heat transmission, which concentrate mainly on the problem of design. The author himself made some contribution to the knowledge of heat transfer and has considerable experience in design and manufacture of equipment, which he gained as a leader of a development group with ESCHER WYSS of Zurich.

Part 1 of the book, which comprises roughly half the printed pages, is primarily concerned with the theory of heat transfer and contains design formulae and diagrams for the estimation of heat transfer coefficients and pressure drops. This section is somewhat out of balance. It is difficult to see why so much space (over 100 pages) is devoted to boiling and condensing coefficients, which are treated with superfluous thoroughness, whereas forced convection is dismissed in a few pages. The boiling and condensing section is overwhelmed with theoretical details, complicated and lengthy expressions of doubtful validity and usefulness, as for instance, on the effect of surface roughness on film condensation or the effect of bubble size on the boiling heat transfer coefficient. It would have been wiser to restrict the theory to minimum and concentrate on useful correlations and working equations. Perhaps in future editions more attention is given to the condensation of mixed vapours and condensation in the presence of an inert gas. Part 2 is concerned with mean temperature differences and dirt film factors. Part 3 describes procedure for an economic design of heat exchangers and Part 4 gives details of construction and mechanical design of standard and less orthodox equipment. Some of the data here are of little interest to British chemical engineers, as they refer to specific codes and standards not applicable to this country. Part 5 deals with the operation of heat exchangers and includes methods of estimating economic cleaning cycles and practical hints on cleaning of heat exchangers.

The book is well illustrated with diagrams and photographs of full scale equipment and contains numerous worked examples. Bibliography is excellent and up-to-date. The text is written for both design engineers and plant personnel but it should also be useful to students who can benefit particularly from the sections on construction and operation and obtain an insight into the practical aspects of heat transfer equipment. Although there are numerous and well established texts on this subject, this book deserves its place as a complementary volume to MCADAMS and KERN.

Scientific Research in British Universities, 1960-1961
D.S.I.R., 375 pp., £1.12.6d. H.M.S.O.

THIS volume lists the subjects which formed the basis of scientific research at British Universities and their affiliated Colleges during 1960-1961. It will be a valuable reference source for all seeking information on the scientific research activities at British Universities.

Chemical Engineering research is carried out at the following Universities. Birmingham; Cambridge; Durham: Kings College, Newcastle upon Tyne; Edinburgh; Glasgow: Royal College of Science and Technology, Leeds; London: Imperial College, King's College, University College; Manchester: College of Science and Technology; Wales: University College, Swansea. Research at Technical Colleges was unfortunately omitted.

Thermodynamics
By G. N. Lewis and M. Randall (second edition) revised by K. S. Pitzer and L. Brewer.
McGraw-Hill Book Co. Inc., New York, 1961. 723 pp., 97s.

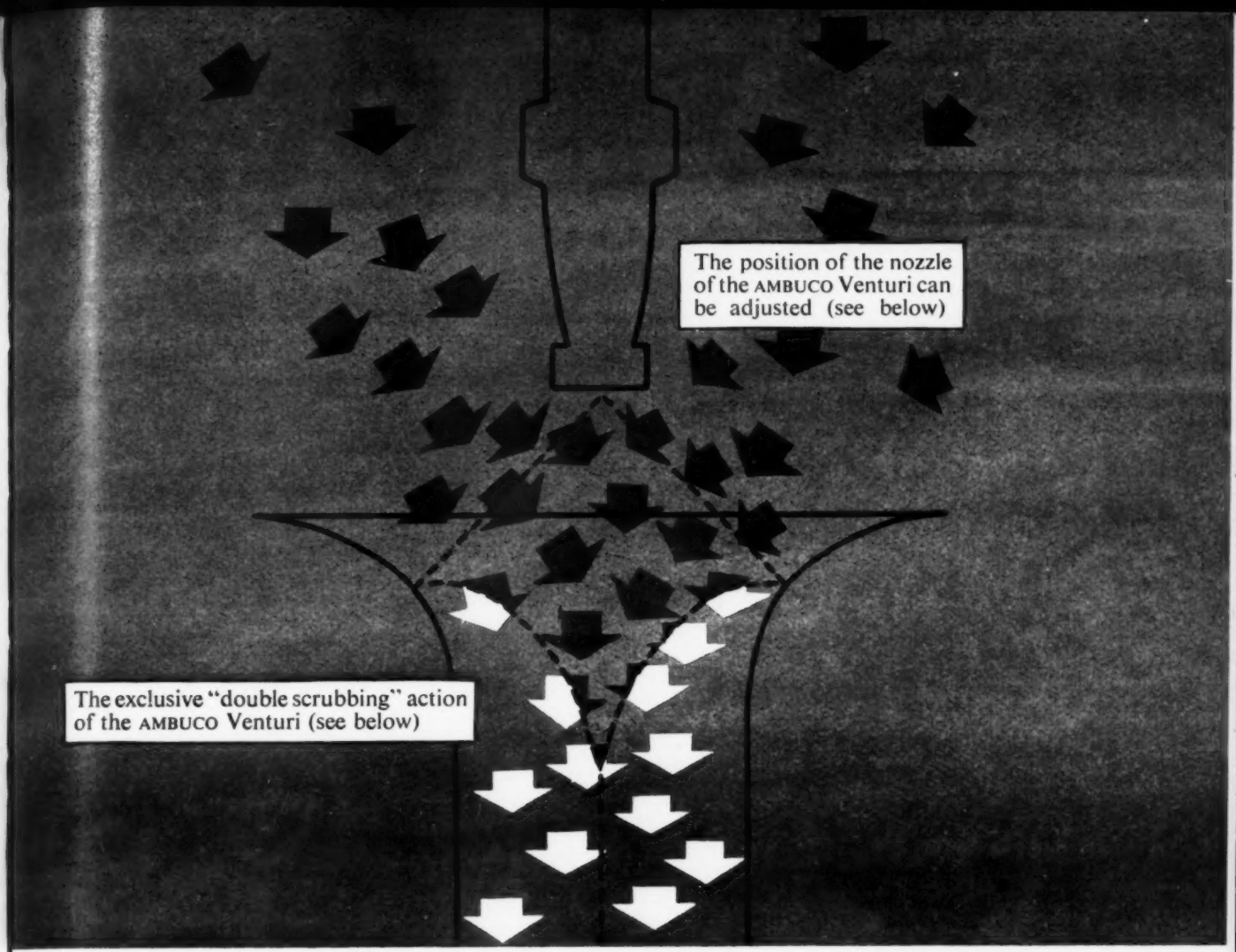
ALTHOUGH this book is described as a new edition of the classic text-book by LEWIS and RANDALL, first published in 1923, it is, in effect, a completely new book written by two notable contemporary thermodynamicists, PROFESSORS PITZER and BREWER.

The book is much larger than its predecessor, 600 pages divided into 33 rather short chapters, together with 10 appendices and comprehensive subject and author indexes. Failure to group the chapters necessitates some searching if information on a particular topic, for example chemical potential, is desired. Very roughly, the chapters could be placed in the following sections: (i) Chapters 1 to 8: the first two laws of thermodynamics; (ii) Chapter 9: cyclic processes; (iii) Chapters 10 to 15: Entropy and the other state functions, the third law and chemical potential; (iv) Chapter 16: real gases; (v) Chapters 17 to 25: properties of solutions, particularly electrolytes; (vi) Chapters 26 to 33: other topics including surface effects, electric and magnetic fields, vaporization processes and hydrogen and helium at low temperatures.

This edition, like its predecessor, presents a clear picture of the basic principles (in its early chapters) and attempts to retain this approach in tackling a very wide variety of topics.

Although now superseded by more specialized texts for undergraduate chemical engineers, it can be recommended for reference particularly in those topics not normally considered part of the standard thermodynamics course.

W. STRAUSS


The position of the nozzle of the AMBUCO Venturi can be adjusted (see below)
The exclusive "double scrubbing" action of the AMBUCO Venturi (see below)

How to stop smoking

BCE 716 for further information

Ambuco Venturi Scrubbers remove chemical fumes more efficiently because....

..... **the exclusive "double scrubbing" action** (Waagner Biro System) of the Ambuco Venturi forces the laden gases to pass through *two* complete cones of water. In the first cone the water droplets are relatively large and travel fast. In the second cone the water droplets are relatively small and travel more slowly, while the speed of the gas and particles increases. The resulting maximum relative velocity ensures highest collection efficiency.

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Tests have shown that Ambuco Venturi Scrubbers will remove up to 99·97% of particulate smokes and aerosols in the range 2 microns to 0·5 micron as encountered in such materials as sodium chloride, ammonium chloride, phosphorous pentoxide, etc. For example, sodium chloride fume with an inlet burden of 4·7 gr/cu. ft. can be cleaned to ·007 gr/cu. ft. above 0·5 micron.

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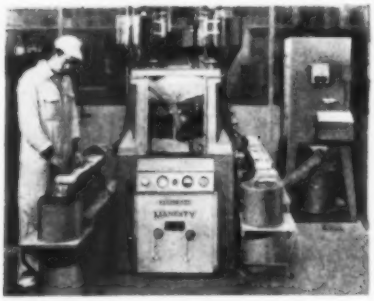
PLANT EQUIPMENT NEWS

Dust Collectors

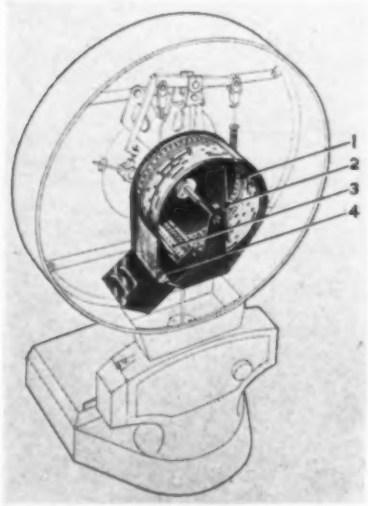


The illustration shows the layout of unit dust collectors applied to tableting machines. Dust is created at the points where powder is tamped into the dies on the machine. In this case, a Unimaster 70 model collector is used and is equipped with electrified shaking gear and quick-release dust container. Smaller machines can be served by a Drytex collector, fitted with hand-shaking gear and a removable drawer for the collected dust. **Dallow Lambert & Co. Ltd., Thurmaston, Leicester.**

BCE 778 for further information

Optical Digitizer and Decoder

Visual readings on a variety of instruments can be translated into digital form for the purpose of operating controls or producing records, using this optical digitizer and decoder. Typical applications are the production of punched tape or cards and/or weight print-out by a weighing machine having a dial scale; the indication of angular position with remote visual indication; the remote weight setting on dial scales; and data logging and machine tool control.



1—coded drum; 2—printed-circuit amplifier; 3—photo-transistor; 4—lens.

The digitizer is a self-contained, totally enclosed unit which houses a transistorized printed-circuit amplifier.

The decoder unit is housed in a separate case. It receives the signals from the digitizer in coded form and translates them by means of relays into three decades 0-9. This can be converted by the fitting of additional equipment into avoirdupois, angles or fractions of the decimal output.

The decoder can be provided with or without an illuminated inline indicator. The unit will also provide the feed for printed, typewritten, punched card or tape output and, if desired, will re-encode for a computer.

This versatile equipment has applications in a large number of industries from the machine and fitting shops to process control installations in the chemical industry where information on flow pressure, temperature and weight is required to control the process of feed information to recorders or computors. **Lindars Automation Ltd., 143 Maple Road, Surbiton, Surrey.**

BCE 779 for further information

Carbon Monoxide Detector Plate

This new detector monitor consists of a small 5 × 5 cm plate with a disc-like insert containing a special sensing substance, the active principle of which is Palladium chloride suspended in a silica gel. In the presence of CO gas the Palladium salt is reduced and the disc turns grey or black, depending upon the concentration of the gas. 0.01 per cent CO is detected in under 15 min, 0.02 per cent CO in 5 min, and 0.05 per cent immediately.

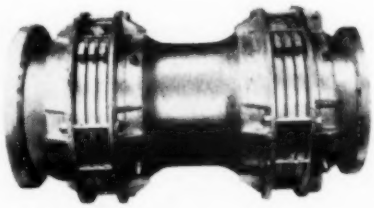
The disc can be regenerated in ½-3 hr by exposure to air, and it can be used several times without affecting its efficiency. However, too long or too strong an exposure causes irreversible reaction. The disc is not affected by petrol fumes. The U.K. distributor of this Danish invention is **Herzbi Ltd., 57 Lordship Park, London, N.16.**

BCE 780 for further information

Thin-wall Bellows Expansion Units

Parsons & Co. have arranged to manufacture, under licence in Britain, the Zallea range of packless expansion joints. Zallea Bros., of Delaware, U.S.A., are the world's largest manufacturer in this field, and these joints have been used in a wide range of piping applications in the oil and chemical industries.

Bore sizes available in Britain will range from 3 in. to 48 in., and the units will accept pressures up to 1000 psi and temperatures between −320°F and +1600°F. The axial deflection for one corrugation can be as much as ¾ in. with a total compression force of less than 160 lb



per inch of diameter. The joint consists of a corrugated bellows attached usually by welding to a pipe end or flange. For pressures of less than about 50 psi and limited movement this is adequate, but for greater pressures equalizing rings are fitted. The bellows corrugations, usually of austenitic stainless steel some 0.050 in. thick, are hydraulically formed. Full production is expected by mid-1962. **C. A. Parsons & Co. Ltd., Heaton Works, Newcastle upon Tyne.**

BCE 781 for further information

Hand-operated Diaphragm Acid Pump

This new portable pump for works duties, such as the emptying of carboys, is simple, robust and light.

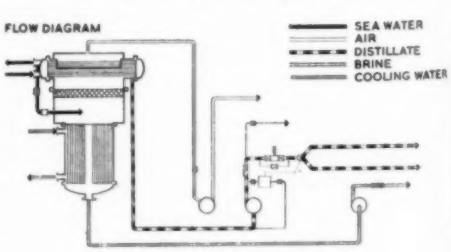
The TK/HODP pump is self-priming and can handle a wide range of acids, alkalis, abrasive and corrosive liquors. It has a minimum of wearing parts and there are no glands to maintain. The hose connections and pump housings are in Petrox "C", a ceramic material which is strong, dense and highly resistant to acid attack. It is also highly resistant to abrasion and can handle slurries. Diaphragms are available in either rubber or Hypalon. The total head is 30 ft and the suction lift 10 ft. **Transkem Pumps Ltd., Sunlight House, Quay Street, Manchester, 3.**

BCE 782 for further information

Distillation Utilizing Waste Heat

A compact sea water distillation plant to utilize waste heat at any temperature above 120°F has been designed, tested and is on the market.

Known as the Aquagenerator, the plant is available in five standard sizes with outputs ranging from 4 tons per day to 30 tons per day. Other sizes can be made to meet customers' individual requirements. It is primarily designed to utilize



BCE 717 for further information

SUPER-D-CANTER

"May I suggest M'sieu"

"Tonight, number seven will be your lucky number at the tables, M'sieu. The croupier is my brother, M'sieu. But I have it on even better authority that Sharples are giving a complete engineering service on any process connected with separation. Thank you M'sieu. Vive la separation."

SHARPLES – *chemical engineers as well as makers of centrifugal equipment*

P25

SHARPLES CENTRIFUGES LTD., TOWER WORKS, DOMAN ROAD, CAMBERLEY, SURREY. Telephone: Camberley 2601. Telegrams: SUPERSPIN, CAMBERLEY

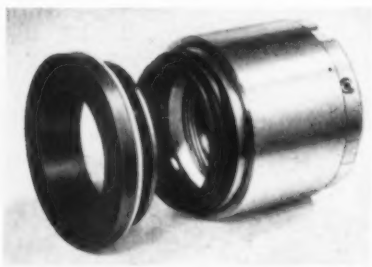
PLANT EQUIPMENT NEWS

diesel engine jacket cooling water at temperatures between 145°F and 160°F, but other sources of low-grade waste heat as low as 120°F can be used.

Distillation takes place under a high vacuum and there is an almost complete lack of scaling because of the very low boiling temperatures. The design details incorporated have resulted in a plant that is far better in many respects and considerably more compact for equal outputs than other similar plants that are available. For example, the third plant in the range, with an output of 11 to 15 tons per day, has an overall height, including the base plate, of 8 ft 9 in. The overall length is only 4 ft. All necessary pumps and equipment are contained within these limits. The other unit sizes in the range are similarly compact. **Buckley & Taylor Ltd., Castle Iron Works, Oldham, Lancs.**

BCE 783 for further information

Mechanical Shaft Seals



These have been designed for service at higher pressures than have so far previously been provided for by any mechanical shaft seal in standard commercial production. The types 51B and 52B (illustrated) have a good performance life considering pressure, temperature, shaft size and shaft speed. They have a designed nominal pressure ceiling of 1500 psig, and at present are supplied in sizes ranging from 15 mm to 100 mm, rising by 5-mm steps. Type 51B has rubber components (i.e., the "O" rings, to seal against air, water, mild chemicals, solvents, lubricating oils and refrigerants), and type 52B has no rubber components and is recommended for highly corrosive services. Their respective temperature ranges are −40°C to +100°C and −80°C to +250°C. **Crane Packing Ltd., Slough, Bucks.**

BCE 784 for further information

Lightweight Folding Containers

These pallets, which can be handled by a fork truck, have knock-down sides and ends. The frame is of angle iron and the sides of welded wire mesh. One side can be removed to convert them into bins. They are easy to stack and fold. **Forges & Ateliers de Commercy, Commercy, Meuse, France.**

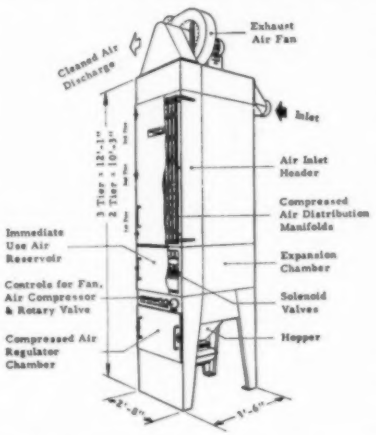
BCE 785 for further information

Automatic Fabric Filter

A new particle collector, developed by Dallow Lambert, employs limited quantities of compressed air as a cleaning medium, embodies the fundamental dynamic air flow characteristics generally associated with some blow ring-type filters, but has no mechanical moving parts. The basic design incorporates an integrated system of standard filter units in such a manner as to enable installations to be assembled capable of handling air volumes in the order of 100,000 cfm or more if required.

In simple form it may consist of one-, two- or three-tier assemblies, mounted on a hopper, silo pressure vessel or conveyor to suit the individual application.

Multi-assemblies of the unit shown in the diagram can be achieved in a side-by-side arrangement, back-to-back, or a combination of both. The maximum fabric area of a single unit is obtained by three tiers, giving, at present, 180 sq ft of fabric. Multi-assemblies increase filtration area accordingly. Filtration velocities obtained are substantially greater than those experienced with filters of orthodox design, and a single three-tier assembly would have a continuously rated gas throughput, on average, in the order of 2000 cfm, varying from 1000 cfm for dusts with obnoxious filtration characteristic to more than 3000 cfm for dusts with benign behaviour. The control of pressure drop caused by the deposition of collected dust on the filter medium is exercised by subjecting each vertical row of filtering elements to a concatenated cleaning cycle. An adjustable pressure regulator maintains the correct working pressure



in the "immediate use" air reservoir; water traps, relief valves and drain are fitted as standard, where required. The filter has virtually 100 per cent filtration efficiency; high filtration velocities; no mechanical moving parts; and economy through use of standardized components. **Dallow Lambert & Co. Ltd., Thurmaston, Leicester.**

BCE 786 for further information

Withdrawable Immersion Heater

A new withdrawable-type immersion heater has just been put on the market. A feature of this heater is that ceramic formers for carrying the resistance wires have been replaced with a magnesium-

oxide-sheathed element which is fitted into a pocket.

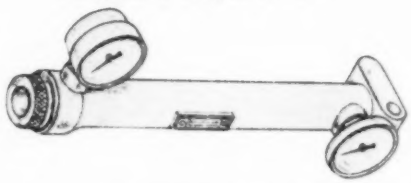
The heating element makes close contact with the pocket; this results in a high transfer efficiency and a high loading for a given length.

This type of heater is practically unbreakable, so maintenance is reduced to a minimum.

The illustration shows an "Eltrofin" oil immersion heater partly withdrawn from the pocket, and having a thermostat incorporated in a 2¾-in. B.S.P. head. **Eltron (London) Ltd., Accrington Works, Stratmore Road, Croydon, Surrey.**

BCE 787 for further information

Compressor Output Tester



A 500 cfm air compressor, which is only 10 per cent down on output, costs an extra £220 per year to run. A compressor output tester has been designed to enable quick checks of compressor performance to be made by the normal maintenance personnel. It consists of an accurately machined nozzle fitted at one end of a steel body, the other end being screwed to fit on to the off-take cock. A pressure gauge and a thermometer are fitted to the body. Two sizes are available, Model 4 (£29 9s.) for nozzles up to $\frac{7}{16}$ in., and Model 6 (£40) which will take all nozzles. Different sizes of nozzle may be fitted to adjust the range of the tester. **Alan Muntz & Co. Ltd., Bromwells Lane, Feltham, Middlesex.**

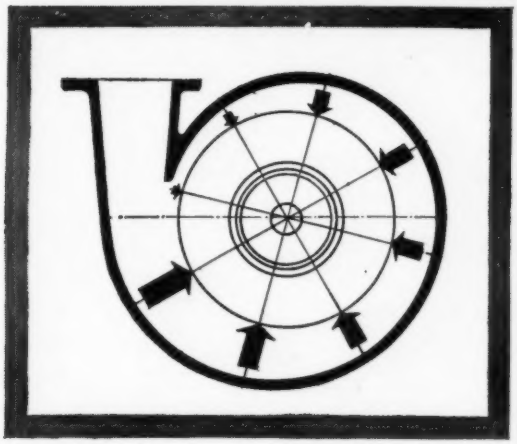
BCE 788 for further information

Dustless Powder Unloading and Conveying

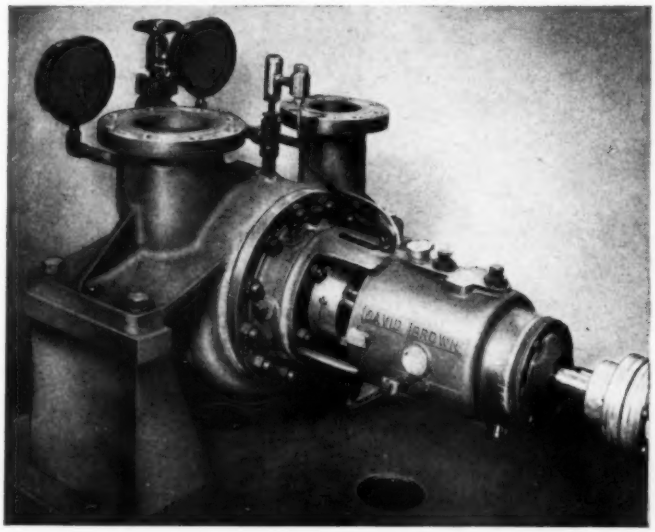
Modern powder handling techniques demand dustless conveying. This particular system gives rapid handling—from 5 cwt to 12 tons per hour—of fine chemicals in the micron or sub-micron range. It is therefore labour-saving and perfectly clean in operation. Operators are protected from toxic danger conditions and the product is free from contamination.

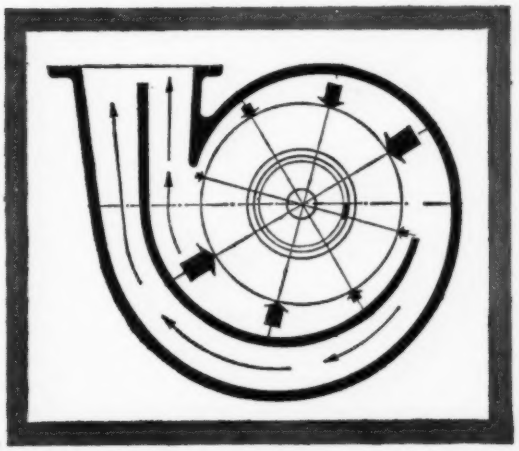
There are two types of conveying system available; the first is shown in the photograph and uses the services of an operator to draw out by suction, through a flexible hose, a quantity of powdered material, which then enters a cyclone for

Why HYDRAULIC RADIAL BALANCE makes so much difference to the life of a centrifugal pump



See how the outdated single volute construction promotes uneven pressure around the periphery of the impeller, causing excessive bearing wear, excessive maintenance, excessive costs !





Double volute construction of David Brown 'Bingham' Pumps ensures equal pressures on opposite sides of impeller, giving hydraulic radial balance. Result—long life, infrequent maintenance.

'Bingham' double volute centrifugal pumps

—cast, machined, assembled, tested under one roof by

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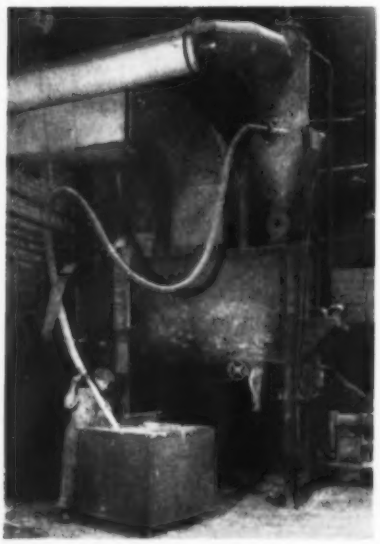
PLANT EQUIPMENT NEWS



air powder separation. The product is then unloaded through a rotary or other type of valve into a hopper or, as in this case, a mixer.

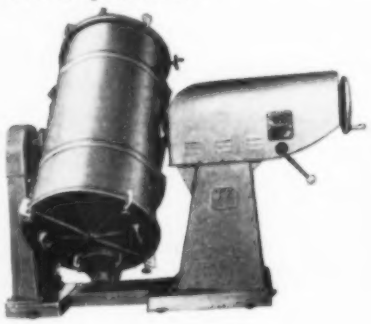
In the second type of plant no labour is involved in the conveying of the material, since the powder to be conveyed is dropped from a storage hopper through a rotary or similar valve into the pipeline through which a high-speed stream of air passes, conveying the material to the combined filters and storage hoppers. In these units the conveyed material is separated out and dropped by gravity into a further process or storage hopper.

Successful plants of this type have been provided and installed for the handling of pigmentary colours; zinc oxide; alumina; iron oxide; rice powder; flour and hydrated limestone amongst others. **Bivac Air Co. Ltd., Marsland Street, Stockport.**

BCE 789 for further information

Powder Blenders

This unique range of machines, covering working capacities of ¼ to 80 cu ft, is designed for the rapid blending of powders of any type, chemicals, flakes or crystals. Agglomeration is eliminated and there is the added advantage of being able to reduce particle size.



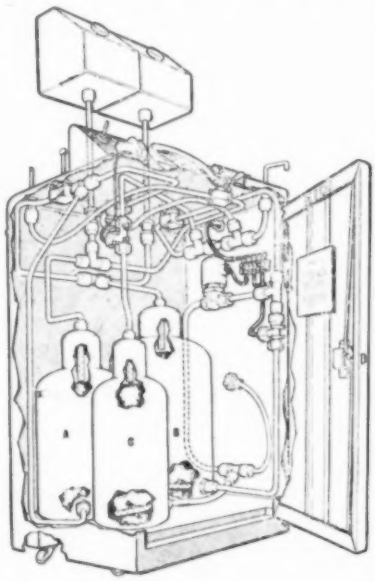
Vessels are of stainless steel, aluminium, mild steel or acrylac, depending on requirements, and are readily detachable and interchangeable, avoiding any possibility of contamination when changing from one formula or colour to another.

The machines have been critically tested using a wide variety of products, including: plastic moulding powders and dry colouring, photographic chemicals, pharmaceutical products, porcelain aggregates, metallic oxides, food chemicals, tobacco blends. **T.P. Chemical Engineering Ltd., 5 Thornhill Road, Croydon, Surrey.**

BCE 790 for further information

Water Deionizers

Where huge volumes of 2000 gal/week or more of ultra pure water are required, a large ion exchange plant with efficient and perhaps automatic regeneration will fulfil the need. For smaller users requiring less than 200 gal/week a smaller "cartridge type" unit would be sufficient. Deionizing apparatus to fulfil the above needs have been on the market for some



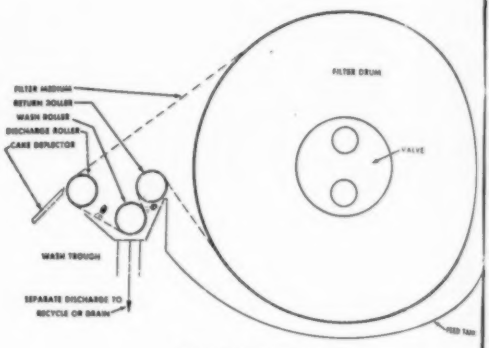
time, but the makers have now produced an intermediate model, the "Elgastat" Type E.101, for the user who wants between 200 and 2000 gal of purified water per week.

It will produce purified water B.P. at the rate of 50 gal/hr and regeneration is superseded by a simple charging cycle. A prepurifier removes the gross contamination from the tap water and the final purification of the effluent is carried out by a mixed bed cartridge. The Type E.101 (illustrated) costs only £210 with no installation fee. **Elga Products Ltd., Lane End, Buckinghamshire.**

BCE 791 for further information

Continuous Discharge Rotary Vacuum Filter

The outstanding feature of this new rotary vacuum filter is that the belt is continuously removed from the drum, cleaned and returned to the drum with each revolution. Thus a clean filter medium is always used giving a high filtration efficiency. In many cases this filter will handle slurries which cannot otherwise be filtered continuously.



THE EIMCOMBELT FILTER

The continuous discharge vacuum filter will find many applications in the chemical, petroleum, food, mining and metallurgical industries, as well as in sewage plants and general processing fields. It is manufactured in standard sizes ranging from 18 in. dia. by 12 in. face to 14 ft. dia. by 16 ft face. The smaller models are used in laboratories and pilot plants, and the larger ones cater for almost any industrial filtration requirement.

In each filter cycle the belt is removed from the drum and passed round a small-diameter discharge roller. The sharp change in radius discharges the cake from the belt, and flexing of the belt extrudes cake from the weave. The belt then passes round a wash roller and is cleaned on both sides by high-pressure fluid jets. These can be operated continuously or intermittently, and the amount and force of the spray can be adjusted to suit operating conditions. The belt alignment is maintained automatically by the movement of a special roller.

A range of filter media is available to meet any requirement. A special corrosion-resistant woven metal belt with an exceptionally long service life can be used with coarse or fibrous solids. Belts resistant to almost any form of chemical attack can be chosen from a range of modern synthetic fabrics.

The Eimco Belt is claimed to operate continuously at 80-90 per cent peak capacity, performing as efficiently at the end of a run as at the beginning. This high filtration rate, coupled with short downtime for cleaning, offers substantial savings in process time and costs.

The unit was developed by the **Eimco Corporation of America** and is being manufactured by **Eimco (Great Britain) Ltd., 190 Piccadilly, London, W.1.**

BCE 792 for further information

LEONARD SMITH (ENGINEERS) LTD.

ANNOUNCE A DIVISION

Fabricating orders and enquiries are now being handled by our subsidiary, ASME Vessels Ltd.

The new works, now well-established, will undertake fabrication in Stainless Steel, Nickel, and Aluminium for customers and for its parent Company Leonard Smith (Engineers) Ltd.

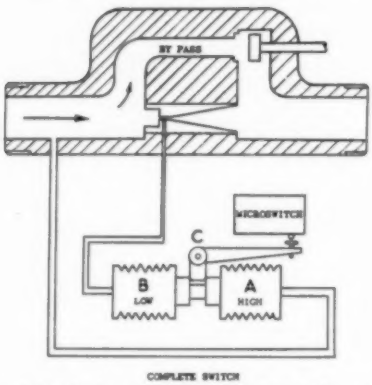
The Chemical Engineering Service will continue to be given by Leonard Smith (Engineers) Ltd. as before.

Class 1 approval for Stainless Vessels

LEONARD SMITH (ENGINEERS) LTD.
ASME VESSELS LTD.
12 HIGH STREET · GILLINGHAM · KENT
Telephone: Gillingham 50163/4 *Telegrams: Eeless Gillingham, Kent*

PLANT EQUIPMENT NEWS

Combined Flow Failure Protection Switch and Flow Rate Indicator



COMPLETE SWITCH

This device may be adapted to different forms of control in high- and low-temperature or corrosive industrial processes, due to the basic simplicity of its design.

It can be fitted directly into piping systems from ¼ in. up to 36 in. in diameter, and depends on the differential pressure across a venturi, which is used to operate a system of metal bellows. The movement of the bellows is transmitted mechanically to an electrical circuit, or through a differential transformer to various kinds of meter, according to the flow conditions which are to be controlled or monitored. It thus can be used either as an alarm device or as an indicator of progressively changing rates of flow.

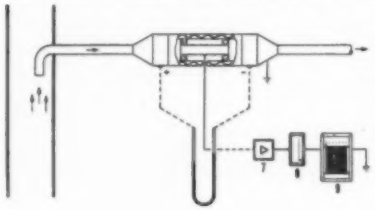
Various models are available in gunmetal or stainless steel, covering a range of flow rates to suit most applications. They are in general use in nuclear power, X-ray and welding equipment, in high power radio and radar transmitters, in compressed air and refrigeration plants. A flameproof version can be supplied. Others for use in gas flow lines or for highly corrosive fluids are being developed. **Nash & Thompson Ltd., Hook Rise, Tolworth, Surrey.**

BCE 793 for further information

Electrostatic Dust Meter

This new instrument will determine the gas content of hot or cold waste gases, or air. It is simple, sturdy, and can operate over a wide temperature range in conjunction with alarm systems.

The basis of "Konitest's" operation is the electrostatic charge generated by friction when a sample of dust-laden air is whirled in a chamber. The magnitude of this charge depends on the physical characteristics of the dust, and a table is provided for calibrating the instrument for various dusts. The relationship between the registered readings and the dust content is linear. **J. C. Eckardt A.G., Stuttgart, Bad Cannstatt, Germany.**

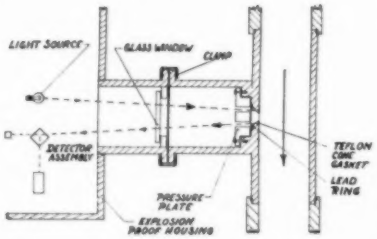


BCE 794 for further information

Refractometer for Measurement of Opaque Streams

Fluid process streams which previously could not be measured accurately because they were highly viscous, extremely dark, opaque or because the physical character changed when a sample was removed from the process can now be measured by a new in-line refractometer.

Streams of this type are encountered in the chemical industry in polymer processes; in the petroleum industry where dark crude oils are used; in the plastics industry where highly viscous products are involved and in numerous other process industries. Previously these streams could not be suitably measured because a sample had to be removed from the process and transported to some remote analyser. The "Waters" in-line refractometer is actually mounted on the process line, tank or vat. It makes uses of the critical angle technique in analysing the stream. The operation of the instrument is illustrated by the schematic diagram.



The significant feature of the in-line refractometer is that it measures the refractive index at the surface of a liquid sample, and, since surface reflection requires no penetration of light beam into the solution, the instrument may be used for highly opaque and various murky solutions and suspensions as well as transparent solutions. A thermistor imbedded in the housing with the prism measures the process temperature, and by means of a compensating circuit corrections are made for normal variations in process stream temperatures. To prevent coating of the prism when analysing fluids which tend to stick to surfaces easily, a wiper can be provided which will wipe the prism surface periodically.

Heads with prism mounted therein can be provided for the lines from ¼ in. to 2 in. in diameter. **Scientific Furnishings Ltd., Poynton, Cheshire.**

BCE 795 for further information

New Publications

Laboratory-scale Control Equipment. A catalogue (including prices) has just been issued which provides details of Tecam laboratory equipment. The units described are: heating and temperature control unit, s.s. water bath, constant-level device, recorder of small temperature changes, viscometer with micro unit, gelation timer, and optical goniometer. A separate technical note (available for 1s.) shows how the "shear stress" and "velocity gradient" of a non-Newtonian fluid can be determined with the Techne influx viscometer. **Techne (Cambridge) Ltd., Duxford, Cambridge, England.**

BCE 796 for further information

Moment of Decision. This new book describes the Hayward Tyler apprentice training schemes. It is designed for boys about to leave school who have to make the first important decision in their lives —the choice of a career. Additional booklets give details of the three grades of apprenticeship available: student, technician and craft apprenticeships. Copies are available from **Training Officer, Hayward Tyler & Co. Ltd., Crawley Green Road, Luton, Bedfordshire.**

BCE 797 for further information

Electrostatic Precipitation. This 76-page publication (No. 7018) is a comprehensive manual of electrostatic precipitation equipment manufactured by Sturtevant Engineering Co. Ltd. Numerous illustrations show the application of these precipitators in power stations, cement works, steel works, non-ferrous metalling works and chemical plants. **Sturtevant Engineering Co. Ltd., Southern House, Cannon Street, London, E.C.4.**

BCE 798 for further information

Cooling Tower. A recent brochure gives details of the Head Wrightson-Fluor Series 1 cooling tower which is designed specifically for small industrial and air conditioning applications. Towers are available in three standard sizes ranging from 100,000 to 600,000 Btu/hr (25,000 to 150,000 Kcal/hr). Two or more single-cell units may be used, although where more than three Series 1 towers are needed it may be advantageous to consider Series 2, 3 or 4 low head cooling towers. **Head Wrightson Processes Ltd., 20/24 Old Street, London, E.C.1.**

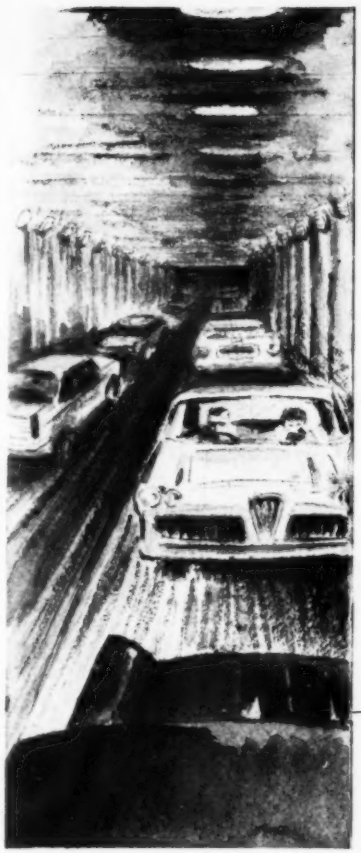
BCE 799 for further information

"Thermocal" DF. A small 8-page brochure provides charts and tables which present the physical properties of "Thermocal" DF Heat-transfer Medium.

"Thermocal" DF consists essentially of ethylene glycol which is miscible with water in all proportions, depresses its freezing point and raises its boiling point. Aqueous solutions of "Thermocal" DF can be used as heat-transfer media where water is unsuitable, in the range −40° to 100°C. **Heavy Chemicals Division, I.C.I. Ltd., Billingham, Co. Durham.**

BCE 800 for further information

BCE 720 for further information



MAKING "Underground Movements" SAFE

The increase in motor traffic is forcing more and more vehicles underground—in garages, tunnels and underpasses. This "movement" can be dangerous unless adequate ventilation is maintained, because of the toxic effects of even small concentrations of carbon monoxide in the atmosphere.
Because this is so well known, there may even be a tendency to over-ventilate these areas, and this can be unnecessarily expensive.
Cambridge carbon monoxide analysers have in the past been installed in a number of *tunnels — and several new outfits using a very much improved analyser have been ordered for major projects under construction.
The new Cambridge equipment, which is now extremely compact, varies in specification according to individual applications, but is generally comprised as follows:

(1) One standard analysing unit for approximately every 300 ft. of tunnel of normal proportions.

(2) Electronic Recorder (or Recorder/Controller) for single or multipoint operation, and calibrated normally 0 to 400 parts per million CO and, if required, with control or alarm facilities at any desired point on the scale.

(3) *Test facilities.* A portable calibration unit is supplied to enable periodic checks to be made on the instrument zero.

*When the first Mersey Tunnel was built, Cambridge-Katz analysers — 12 in all — were installed there with recorders and remote alarm indicators. This equipment, and several similar outfits, have been in continuous operation without breakdown for over 25 years.

Please write for further details, quoting reference AR/11/61. We will be pleased to discuss any project in which you have an interest.

Cambridge GAS ANALYSERS

CAMBRIDGE INSTRUMENT COMPANY LTD. 13 GROSVENOR PLACE, LONDON, S.W.1

NOW!

A NEUMO DRUM PUMP
To take *any* of the well known
Neumo two part motors . . .

Supaversal Pump Unit with pump 8½" long.

Supaversal Pump Unit with pump 47" long.

Pumps can be manufactured from the very wide selection of materials usually associated with the Neumo range.

NEUMO SUPAVERSAL

AIR OPERATED PUMP UNIT

This two gallon per minute pump is ideally suited to the transfer of viscous liquids from drums. Any size Neumo motor can be fitted thus enabling power to be increased as required, to deal with an extremely wide range of viscosities and delivery pressures.

As the pump is always at the lower end of the unit suction lift is advantageously reduced to a minimum.

Supaversal pumps are however capable of considerable suction lifts if desired. The unit can be purchased by the foot and so you pay only for what you require. Pumps vary in length from 8½" to 12'.

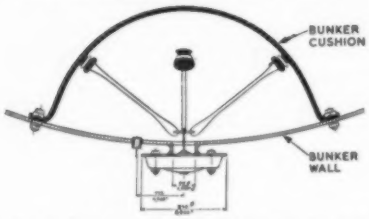
The simple almost straight-through flow system and the large unobstructed valve orifices add to the suitability of the Supaversal for viscous liquids. The Supaversal pump being double-acting produces little pulsation in the liquid flow but this is further reduced by a built in pulse bottle.

Write for details to:-
NEUMO LTD. SOUTH COAST ROAD, PEACEHAVEN, SUSSEX. *Tel: Peacehaven 2544/6*

BCE 721 for further information

PLANT EQUIPMENT NEWS

Anti-bridging Device for Bunkers



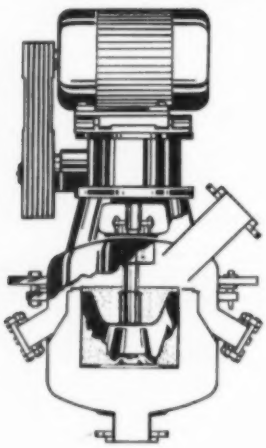
In order to avoid what is sometimes a dangerous and often an unsatisfactory procedure for breaking up bridging or funnelling in bunkers, that is by means of manually- or mechanically-operated pokers, bunker cushions have been developed to provide automatic break-up of restrictions and bridges.

The cushions can be fitted in most types of bunker or silo and consist of an iron base plate and a soft rubber diaphragm. The diaphragm, securely attached to the bunker walls, is inflated to a hemispherical shape by compressed air at 2/4 atm. The operation of the diaphragms can be controlled by push-button devices which can be grouped together on a panel situated at a convenient position. The cushions, which are operated either in succession or individually, are manufactured by Clouth, Rheinishche Gummiwarenfabrik A.G., Cologne, and are now available in Britain. **Orthos (Engineering) Ltd., 62 Coventry Road, Market Harborough, Leics.**

BCE 801 for further information

Homogenizing and Mixing Mill

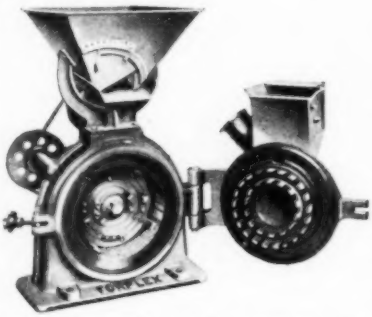
A pipeline mill, capable of high- or low-pressure operation, suitable for breaking up agglomerates and for the emulsification and the preparation of suspensions, has been recently introduced into this country. Designed by Alexanderwerk A.G., Remscheid, it consists of a high-speed rotor with blades moving with close clearance inside a cylindrical cage. The cylinder, which is perforated, can be obtained in various special materials such as 18-8-2 stainless steel. A supporting ring is supplied on the shell of the machine to enable it to be fitted conveniently within an existing plant. It is suitable for operation at 15 atm. **Orthos (Engineering) Ltd., 62 Coventry Road, Market Harborough, Leics.**



BCE 802 for further information

Concentric-hammer Grinding Mill

A mill is now available for grinding soft to medium hard materials in which the grinding elements are interchangeable, and so a wide range of products can be ground at various outputs with each model. The change over from one grinding element to another is carried out rapidly through a hinged door on the face of the mill chamber.



Grinding is effected by a rotating disc fitted with concentric hammers running between the teeth of a disc located on the door of the mill chamber. The particles of material are ground by continuous and high-frequency attrition between the rotary and static grinding elements, and are thrown against a circular screen which surrounds both grinding elements.

Rotation creates a draught which expels the fines through the screen, while the coarse material is forced back for further grinding. If it is necessary to grind the material to below the sieve range, multiple-pin, high-speed and static elements are used, and the particle size can be controlled by varying the speed of rotation. This arrangement is also claimed to be effective for substances which tend to clog the screen.

The Forplex mill is fitted with an automatic and adjustable feeder, and the ground product is received by a take-off hopper fitted to the base of the mill chamber. Alternatively, the material can be collected pneumatically.

It is produced in various sizes which can handle from 14 lb per hour to 5 tons per hour, depending on the nature of the material.

The mill has found applications in foodstuffs such as sugar, spices and cereals and chemical products such as plaster, pigments, resins, fertilizers, cosmetics, pharmaceutical and biological products. **Russell Constructions Ltd., Russell House, Adam Street, London, W.C.2.**

BCE 803 for further information

New Publications

Hardinge Thickeners. An 8-page illustrated publication (G 6010) demonstrates the applications of the Hardinge thickener, a machine for removing the maximum amount of liquid from a mixture of liquid and finely divided solids. One feature of this equipment is the Auto-Raise device, which automatically raises the sludge removal mechanism if there is an overload or obstruction in the bottom of the tank. **International Combustion Products Ltd., 19 Woburn Place, London, W.C.1.**

BCE 804 for further information

Ring Balance Meters. The full range of ring balance meters produced for measuring and recording fuel flow is described and illustrated in a new 10-page brochure. **Hagan Controls Ltd., 14 Grosvenor Place, London, S.W.1.**

BCE 805 for further information

Portable and Side-entry Mixers. Three new leaflets provide details of the range of portable and side-entry mixers, including the "Dispersator", which are available from **Premier Colloid Mills Ltd., Hersham Trading Estate, Walton-on-Thames, Surrey.**

BCE 806 for further information

Hy-Contact Tower Packings. This leaflet gives design and other details on Raschig rings, Lessing rings, Intalox saddles, Pall rings, triple-spiral rings, fenske helices and a variety of tower packings. The packings can be made in chemical stoneware, iron-free porcelain, carbon, plastics, ceramics, mild or stainless steel. **Hydronyl Ltd., 14 Gloucester Road, London, S.W.7.**

BCE 807 for further information

By-pass Rotameters for Large Flow Measurement. How measurement and control of flow rates in pipe sizes as high as 48 in. can be done economically is described in this new Bulletin No. 116, which has been prepared especially for engineers and designers who want complete information about capacity determination, flow range data, piping requirements, accuracy and other important engineering details concerning the use of rotameters in by-pass arrangement. For copies write to **Brooks Instrument Co. Inc., Hatfield, Pa., U.S.A.**

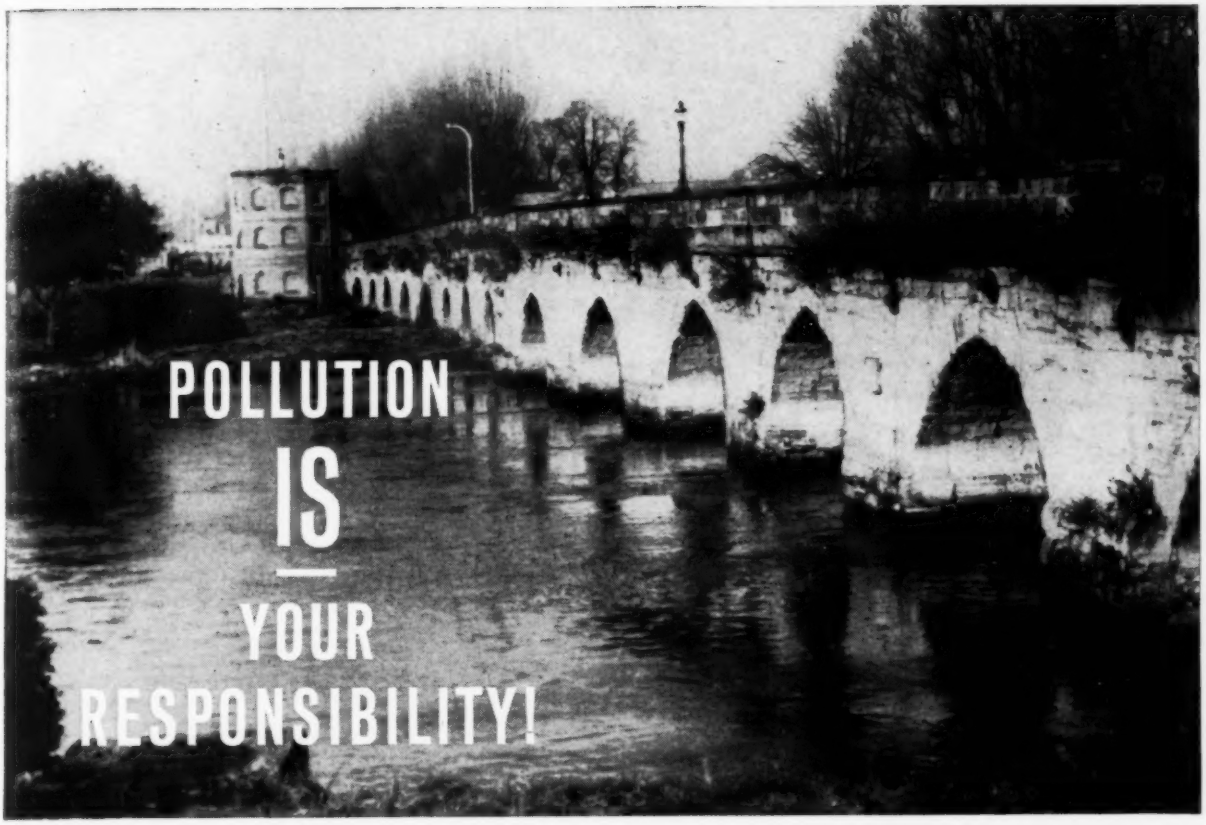
BCE 808 for further information

Lubricants for Oxygen Equipment. Bulletin No. 42 provides details of "Fluorolubes" which are safe lubricants for oxygen equipment. Copies are available from the U.K. distributors of Fluorolubes: **OMNI (G.B.) Ltd., 35 Dover Street, London, W.1.**

BCE 809 for further information

Geared Motors and Reduction Gears. Publication 617 describes the geared motors and reduction gears which are manufactured by **Crofts (Engineers) Ltd., Bradford, 3, Yorkshire.**

BCE 810 for further information



Local authorities and river boards are vitally concerned over industrial pollution of waterways. How large—or small—is your contribution to this problem?

The Prodorite Organisation has extensive experience in the field of effluent treatment of inorganic trade wastes from metal pickling and finishing plants, etc; and are specialists in the design, construction and installations of equipment for their economic and efficient treatment. Prodorite specialists will plan and install a complete effluent treatment scheme to your requirements at *minimum* cost. Operations can be fully or semi-automatic as required.

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This stiff-cover publication contains 25 pages of invaluable information about the products and services of the Prodorite Organisation. It includes photographs of actual installations and details of the Prodorite research, development and consultation services. Technical information is also available in leaflet form. Please quote reference number **P. 103.**

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World of Chemical Engineering

Conferences

Water in Industry

Problems of water supply and the treatment of waste waters and effluents generally have been the subject of recent conferences in Europe and America. In the United States the Water Pollution Control Federation Conference has just concluded; this laid special emphasis upon the pulp and paper industry.

In Europe, accompanying an international exhibition on the same subject, a conference took place early in October held under the auspices of Pro-Aqua Ltd. A section of this conference was devoted to industrial water economy, and the topics dealt with included the danger of spoiling surface and underground water by mineral oils (W. ZIMMERMANN); safety measures for preventing loss of oil from surface and underground oil tanks (E. U. TRÜEB); and pipelines and protection of ground water (A. DERPA). In this section, MR. G. A. TRUESDALE, of The Water Pollution Research Laboratory, Stevenage, dealt with the present position of research upon the effects of surface-active agents.

Other papers dealt with the problems of water economy in the iron-producing industry (H. POEHLMANN), water usage in the chemical industry (E. ZEHNDER), in the cellulose industry (H. TÖTTERMAN) and in the paper and cardboard industry (F. WULTSCH).

Among the remaining papers were accounts of problems in the petroleum refining industry (M. FAIETA) and a British contribution from MR. A. W. KENNY on the problems affecting atomic power stations. Other fields dealt with were the use of refuse and waste and problems of sewage disposal.

A.C.S. National Meeting

Early in September a wide range of papers, a few dealing with fields of interest to the chemical engineer, were given at the American Chemical Society's 140th National Meeting. A feature of this vast conference, attended by 12,000 chemists and chemical engineers, was the symposium dealing with the science of fire-fighting, believed to be the first of its kind ever to be held.

In another field developments in fuel cells were dealt with, and the problem of water was dealt with from a number of aspects, including the fermentation disposal of waste products.

Superphosphate Manufacturers' Conference

Wiesbaden in mid-September was the venue of the Technical Conference of the International Superphosphate Manufacturers' Association.

Here a number of papers of distinct interest to chemical engineers were given. For example, A. MICHOT (S. A. Metallurgique de Prayon, Belgium) considered the production of concentrated phosphoric acid using phosphate rock of high iron and alumina content. BIGOT and J. P. GIELLY considered in detail that awkward problem of filtering phosphoric acid liquor, and surveyed the various types of filter which are available for this purpose. F. SANDALINAS and R. LOSTE dealt with the kinetics of the transformation of SO_2 into sulphuric acid in the Kachkaroff process.

P. MORAILLON devoted his paper to the continuous manufacture of superphosphate in rotary dens, its history and recent developments, while VAHERVUORI described the pilot-plant recovery of cryolite and activated silica in the manufacture of superphosphate.

Further papers included one on the suppression of dust in fertilizer raw materials and granular products (F. J. HARRIS and T. CRAIG), and H. SCHREIBER described experience in the cooling of fertilizers during manufacture.

New Plants in Brief

T. & H. Smith Ltd., of Edinburgh, are to build a £50,000 fine chemicals extension alongside their existing plant at Gorgie. Also in Edinburgh, the **Scottish Gas Board** are to erect a £31,000 refining plant. The project is designed to link up with the plan for a major pipeline from Grangemouth, taking petroleum industry gas to Granton, where it will be refined for mixture with town's gas. A further pipeline will be laid to Bathgate to distribute the refined gas to the West Lothian area, where a large amount of industrial expansion is taking place. Also in the petroleum industry field, **BP Ltd.** announce that the capacity of the new distillation unit under construction at Antwerp Refinery will be 100,000 barrels per stream day.

The first plant in the U.K. to produce sulphamic acid in bulk in being operated by **Marchon Products Ltd.** at Whitehaven. The acid is being distributed by **Albright & Wilson (Mfg.) Ltd.**

From India it is announced that **KSB Pumps Ltd.** are building a plant near Poona to manufacture pumps designed for a variety of local needs. Production, planned at 800 pumps annually, is expected to begin in 1962.

Plastics and Fibres

A new factory with seven times the present floor space is to be built by **Tough Plastics Ltd.**, of Addlestone, Surrey. This is necessary because of the increase in demand for "Tufplas" and a desire to reduce delivery times for all sizes of contracts to six weeks. There is news from the artificial fibre industry that **I.C.I. Ltd.** have started production of "Ulstron"—their new high-tenacity polypropylene filament yarn. At present production is on pilot-plant scale at the company's Wilton Works, but full-scale production of 5 million lb per annum will commence by the end of 1961. Later, the fibre may be produced at the company's new Northern Ireland site at Kilroot, as well as at Wilton.

New Processes

Yields of 95 per cent, low temperatures and pressures, negligible amounts of by-products and minimum capital investment are among the advantages claimed for the new direct oxidation process for making acetaldehyde from ethylene. The process is licensed from **Aldehyde G.m.b.H.** in Germany. Four such plants are operating in Germany and Italy, and Shawinigan Chemicals Ltd. are the first licensees in Canada.

After a year of research, **Simon-Carves Ltd.** have developed a method of coking Nigerian coal which is of a high volatile, non-coking nature and which has previously been considered unsuitable for the production of metallurgical fuel. This is the first step in a programme aiming at steelmaking in Nigeria. After laboratory and small-scale experiments, 100 tons of the Nigerian coal were delivered for full-scale trials, to establish on a commercial scale, that fuel suitable for iron smelting can be made from it.

The Allied Chemical Corp. have been granted a patent for a new method of producing chemical derivatives from a coal tar oil produced by the low-temperature carbonization of coal. The process is based on rapid pyrolysis of pulverized tar in a chamber at 600-1000°C.

Ammonia and Glycerol Recovery

An American patent has been granted to **Phillips Petroleum Co.** for a new process for recovering ammonia from aqueous solutions containing carbon dioxide.

The liquor is fed to a distillation column which is operated so that a stream of high CO_2 concentration is formed at the central section of the column. This stream is continuously treated to remove the CO_2 and it is fed back to the column. Ammonia is recovered from the top of the column.

Another patent has been granted to **Atlas Powder Co.** for a new process for the recovery of high-purity glycerol from the reaction mixture of the catalytic hydrolysis of saccharides.

The reaction mixture is first vacuum flashed until all glycerol is removed from

WHEN COMPLETE DEPENDABILITY IS ESSENTIAL

In pilot plants and petroleum refineries it is absolutely essential that pipeline couplings must be secure and completely pressure tight. Once again the specification calls for Ermeto . . . Ermeto who provide the largest range of high-pressure pipe fittings in the world, in addition to valves and flexible hose assemblies. Also many non-standard fittings are produced to meet our customers' requirements. Our Technical Advisory Staff are at your service and a copy of the latest edition of the Ermeto catalogue, which is a standard reference for piping layouts, will gladly be forwarded to you on request.

COUPLINGS : VALVES : FLEXIBLE HOSE & END FITTINGS : STEEL & COPPER TUBE.

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the residue. The vapours are vacuum fractionated to remove most of the glycols and other volatiles. The residue is treated with sulphuric acid, 0.05-2.5 per cent by weight, at 100-140°C for 6 hr, then neutralized and finally vacuum fractionated to produce pure glycerol.

Personalities

The following are some of the appointments announced during the month.

MR. A. GILLIES has been appointed a managing director, and also acting chairman, of Fisons Fertilizers Ltd. MR. H. WESTON HOWARD is to be chairman, and MR. A. C. BALL, managing director of Hayward Tyler & Co. Ltd., a subsidiary of Stone-Platt Industries Ltd. Foamite Ltd. have appointed MR. J. D. SHAPLAND as managing director. DR. D. H. SHARP has been appointed director (technical) of the Federation of British Industries. DR. H. H. ROSENBROCK, of C.J.B. Ltd., has been awarded one of the annual prizes of the British Computer Society for his paper *An Automatic Method for Finding the Greatest or Least Value of a Function*. At the annual general meeting of the British Standards Institution, MR. GEOFFREY CUNLIFFE, managing director of Norcros Ltd., was elected the new president.

Contracts

Export Orders for British Firms

Two more orders for equipment to be supplied by British firms to Russia have been announced. **Simon Handling Engineers Ltd.**, of Stockport, have signed a contract with **Techmashimport**, the Soviet Trade Organization, valued at over £1.8 million. The complete machinery and equipment for handling, storing and automatic weighing of basic raw materials for tyre-making at a new factory near Stalingrad is to be supplied. Also for Russia, **CJB Ltd.** have ordered eighteen control centres, valued at about £70,000, from the Motor and Control Gear Division of **AEI Ltd.** The equipment will be used to control the electric motors in two projected Russian detergent plants.

Another order for **Simon-Carves Ltd.** is to design and supply a coal preparation plant for **Compania Carbonifera e Industrial de Lota** in Chile. Valued at about £200,000, the contract is the first for coal preparation plant that Simon-Carves have won in South America. The plant will be capable of handling 4400 tons/day of coal.

Birwelco Ltd., of Birmingham, have an agreement with **Yuba Consolidated Industries Inc.**, of Oklahoma, to manufacture and sell Aimco Transaire air-cooled heat exchangers in Europe and the Commonwealth. They have already received several large contracts for this type of equipment from both the oil and chemical industries.

The Plessey Co. Ltd. have received a contract to install a remote control and telemetering installation for the Norwich Division of the Eastern Gas Board. The system, which has its control centre at Norwich, will cover eight gasholder sites in the Division.

The installation will display at the Norwich control room the following functions from each of the out-stations: gasholder stock, medium pressure and district pressure, all with high and low alarm indicators. Remote control is provided for booster on/off, volumetric governor and anti-freeze on/off.

Fertilizer Industry

The Power-Gas Corp. Ltd. have been appointed engineering contractors for the building of a £2 million complete ammonia plant to be erected at Grenaa, Denmark. The plant will be part of a new fertilizer factory for **Dansk-Norsk Kvaelstoffabrik.**

A contract for the detail design, supply and erection of the mechanical components of a new compound fertilizer granulating plant has been awarded to **McKee Head Wrightson Ltd.** The plant, which is for **Fisons Fertilizers Ltd.**, will be erected at their Cliff Quay Works, Ipswich.

Petroleum Contracts

A water treatment plant, part of an expansion of the boiler feed-water facility, is to be built at the Fawley refinery of the **Esso Petroleum Co.** The contract, valued at £150,000, has been awarded to **Head Wrightson Processes Ltd.**

Figures compiled by the **Oil Companies Materials Association** show that, in the second quarter of this year, the oil companies ordered materials and equipment to a value of over £25 million. In the first six months of 1961 total consumption of oil products in the U.K. were about 23 million tons, nearly 10 per cent more than in the same period last year.

Company News

Entering an entirely new sphere, the **Kiwi Polish Co. Pty. Ltd.** have acquired all the shares of the **Dominant Chemical Co. Pty. Ltd.** in Melbourne, Australia. This company leads in the manufacture and bulk supply of industrial chemicals for cleaning.

Wm. Boulton Ltd. have completed a collaboration agreement with **F. B. Lehmann, Maschinenfabrik G.m.b.H.**, of Germany. The technical and sales resources of both companies will be amalgamated to exploit the sales of Boulton equipment.

Tough Plastics Ltd., who manufacture "Tufplas", the chemicaly bonded laminate of unplasticized P.V.C. and polyester resin reinforced with glass fibre, have signed an agreement with **Haveg Industries Inc.** to enable them to manufacture and sell the plastic throughout the U.S.A.

Research Reactor Grants

As a contribution to the Greek national programme for developing the peaceful uses of atomic energy, the United States will present the Government of Greece with the sum of $350,000 towards the cost of the 1-MW thermal pool-type research reactor which achieved criticality on July 27, 1961, at the Democritos Nuclear Centre, near Athens.

Greece's Nuclear Centre is appropriately named after Democritos, the man who gave the word "atom" to the world in the fifth century B.C.

A similar grant of $350,000 has been made to the Government of Norway towards the cost of that Government's Zero Power Reactor, NORA, located at the Institutt for Atomenergi, near Oslo.

The U.S.A.E.C. intends to issue a permit to Kansas State University for the construction of a research reactor—100-kW thermal TRIGA Mark II reactor—on its campus at Manhattan. The University plans to use the reactor for educational and research purposes.

The U.S.A.E.C. will also issue a licence to Cornell University for the operation of the 100-kW thermal TRIGA reactor which has recently been constructed on the campus at Ithaca.

Plans to Attract Industry to Ireland

The Irish Government are very keen to stimulate more industrial development in Ireland, particularly from this country. The Industrial Development Authority and the Shannon Free Airport Development Co. Ltd. have been set up to assist firms wishing to establish manufacturing interests there.

At a recent Press conference in London the Chairman of the Authority, DR. J. P. BEDDY, pointed out that many British firms, including such well-known ones as Dunlop, I.C.I., Unilever and Albright & Wilson, have already participated in the development of Irish industry. A programme of incentives has been devised to encourage export industries and attract private capital. Part of this programme includes outright non-repayable capital grants for site and buildings, and help towards training workers and the cost of plant and machinery. There are also valuable concessions under the tax laws. Labour in Ireland is plentiful and wage rates are generally lower than in the U.K.

Of particular interest to the chemical industry is the new oil refinery at Whitegate, Co. Cork, which was established with American and British interests. The authority has appointed a permanent representative in Britain, MR. G. B. MACCARTHY, and he may be contacted for further information via the Irish Embassy in London.

Hydrogen Peroxide Plant for Spain

Laporte Chemicals Ltd., a subsidiary of Laporte Industries Ltd., has entered into an agreement with the Spanish company, **Peroxidos S.A.**, to provide technical assistance and advice on the construction of an autoxidation hydrogen peroxide plant near Saragossa in Spain.

The initial capacity of the plant will be 1 000 tons of hydrogen peroxide annually (calculated as 100 per cent), production planned to start in 1963, subsequently rising to 1500 tons.

Peroxidos S.A. have been incorporated in Spain to deal in chemicals and chemical products, and, in particular, all grades of hydrogen peroxide and its derivatives. Two of the directors will be nominated by Laporte.

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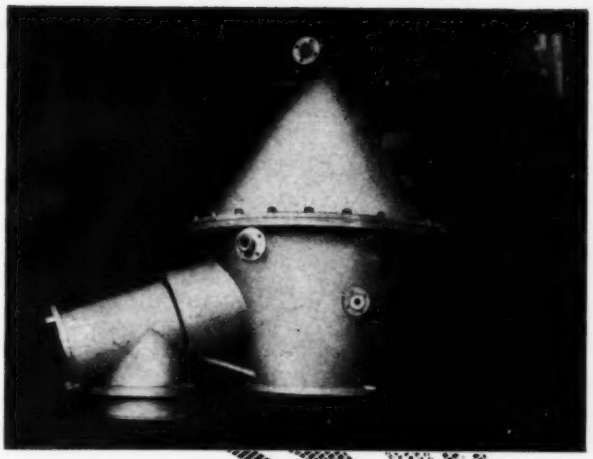

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New Research Laboratories

The first two laboratory buildings specially constructed for the Chemicals Division at the BP Research Centre, Sunbury, are now complete. One of the buildings is specially designed for work on pilot plants, and together they represent an investment of about £½ million. The division was set up in 1958 to handle research on petroleum chemicals.

Problems Solved

Temporary Transportable Gas Holders

The problem of storing gas and supplying consumers while repairing holders at three small gas works where no alternative storage was available has been solved in a novel way by the Northern Gas Board, Newcastle upon Tyne.

They used inflatable rubber bags as temporary gas holders which could be folded up and stored when not in use.

The rubber bags* are rectangular in shape, each 35ft long × 15 ft high × 15 ft wide with a capacity of 7500 cu ft. The fabric is a nylon weave coated with neoprene, has a weft and warp strength in excess of 250 psi, is approximately 0.025 in. thick and folds into a package 8 ft × 3 ft × 2 ft weighing 640 lb.

To provide a minimum district pressure of approximately 4 in. w.g., the top of the holder had to support 8½ tons of ballast.

Apart from prior rough levelling of the site and casting of four concrete corner blocks, the holder took 48 man-hours for erection. The structure can be easily dismantled, transported, stored and re-erected when required.

* Specially made by the General Rubber Goods Division, Dunlop Ltd.

P.V.C. Cuts Maintenance Costs in Chemical Works

To meet the requirements of the Clean Air Act, it was necessary to build the metal chimney of a new sulphuric acid plant* to a height of 150 ft.

The maintenance engineering staff wished to avoid the heavy cost of periodic painting and the possible early replacement of upper sections exposed to acid dewpoint conditions. They decided to protect the chimney with a coating based on Geon P.V.C.

Sections of the 2 ft 6 in. dia. chimney were immersed in a tank containing a paste based on Geon 121 resin,† thus coating both sides and flanges. When gelled, the paste forms a smooth, abrasion-resistant coat with excellent adhesion to the metal. The coat is not affected by weather and requires no form of maintenance. And being corrosion resistant, it protects the interior of the chimney from the acidic conditions of the plant.

In all, 100 ft of chimney were coated (the entire height above factory roof level), and at a recent inspection the effectiveness of the coating was already apparent.

* Installed by F. W. Berk & Co. Ltd. at their London factory.

† Coating was carried out by Plastic Coatings Ltd. using Geon 121 P.V.C. paste resin manufactured by British Geon Ltd., a company in the Distillers Plastics Group.

Corrosion-free Reinforced Plastic Exhaust Stack

A 50-ft-long, 5-ft-dia. self-supporting exhaust stack* has recently been installed at a large mid-West metal refining plant. It is constructed of bonded, fibreglass-reinforced Hetron† polyester resin and is designed to handle over 70,000 cfm of hot corrosive exhaust fumes. This unit is reported to be the largest one of its kind ever constructed. It is capable of withstanding winds up to 100 miles/hr, and requires no steel structure or cables for supports.

Its 15-ft base has no metal supports susceptible to atmospheric corrosion, thus exterior paintwork and anti-corrosive treatment have been completely eliminated. The stack shell is ¼ in. thick at the top and over 2 in. thick at the base of the flange.

* Fabricated by du Verre Inc.
† Produced by Hooker Chemical Corp.

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